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EXPERIMENTAL STUDIES OF THE JUDGMENTAL THEORY OF FEELING: I. LEARNING OF POSITIVE AND NEGATIVE REACTIONS AS A DETERMINANT OF AFFECTIVE JUDGMENTS

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PROBLEM

The objective of the present investigation is the reverse of that sought by numerous studies concerned with the 2 variables, learning and affection. There have been many experimental attacks on the relationship between these 2 factors, in which the dependence of the former on the latter was the goal. The purpose of the present investigation is to determine the dependence of affection on learning. The reader may find a complete orientation to the present problem in the writer's exposition of the Judgmental Theory of Feeling.[1]

The 3 experiments to be described in this paper are presented as a test of the chief hypothesis of the Judgmental Theory, namely, that judgments of pleasantness and unpleasantness are determined by positive and negative reactions to the objects so judged. In the present study, the objects judged as pleasant or unpleasant are Japanese words. The positive and negative reactions are those of pronouncing or of not pronouncing the words. These 2 types of reactions are produced by a conventional learning situation. The method

[1] Peters, H. N., The judgmental theory of pleasantness and unpleasantness, *Psychol. Rev.*, 1935, **42**, 354–386.

of obtaining judgments is that of order of merit. The change in rank order to be expected on the basis of the hypothesis is an increase (greater pleasantness) for those words pronounced and a decrease for those not pronounced. If a change in rank order of this kind is found to result from the learning situation, it may be concluded that the hypothesis is verified in so far as the method allows. On the other hand, if this change does not occur, the hypothesis may be considered seriously weakened.

Experiments 1 and 2

I. Procedure of Experiment 1

All experiments were performed in an 8′ × 18′, relatively soundproof, room. Subjects were taken individually into this room and put through the following 6 steps of the procedure, without interruption, in the order described.

(1) *Ranking the 10 Japanese Words in Order of Preference* (R_1).—The subject was asked to stand before a narrow table located near the entrance to the room. The experimenter placed on the table, in front of the subject, the sheet of typed directions and a pack of 10 cards, saying as he did so, "Will you please read these directions and do as it says with these cards?" The directions read as follows:

Instructions for Ranking Words in Order of Pleasantness

Here are 10 cards with a different Japanese word typed on each one. It has been often remarked that a person's chief reactions to foreign words which are entirely strange to him are emotional—that is, reactions of liking or disliking. In this experiment we are interested in knowing your emotional reactions to these particular Japanese words. The quickest way to get this information is for you to rank the words in order of preference, placing the 10 cards in a straight line with the least preferred (unpleasant) word at the left end, the next to the least preferred word next to the left end, and so on, with the most preferred (pleasant) word at the right end of the line.

The best way to proceed is as follows. Take one of the cards (just any one) and look at the word. Decide whether you think it pleasant or unpleasant. If you think it pleasant, place the card to your right on the table. If you think it unpleasant, place the card to the left side. If you cannot decide, place the card directly in front of you. Then take another of the cards and look at the word. Compare the degree of pleasantness of this second word with that of the first one you put on the table. You will find that this second word seems either more or less pleasant than the first. If it seems more pleasant, place it to the right of the first; if less pleasant, place it to the left. Then take a third card, and decide whether the word is more or less pleasant than the first word, and accordingly locate it to the right or the left of the first word. Do the same with the second word—locating the third card either to the right or to the left. Hence, the third word may be located to the right of both the first and second, to the left of both, or in between. Accordingly you will compare each of the remaining words with those you have placed on the table, until you find the position in the

series to which it belongs. This should be done in a very short time. You should follow your first impulses in this ranking and not spend much time thinking about it.

Please arrange the cards as quickly as you can. In cases of doubt, for instance, as to whether a word should be located to the right or left of another particular one, follow your 'hunch'—that is, put it to one or the other. You may change the relative position of a card as many times as you like. But in the end the 10 cards will be arranged in a straight line along the table.

This sort of thing you will find easy once you have started. It has been done for many different kinds of objects, for instance, colors, pictures, handwriting samples, movie actors, and given names.

The top of the table on which the subject ranked the words was $25\frac{1}{4}'' \times 67''$ in size, and its height above the floor was $35\frac{3}{4}''$. Stiff, brown wrapping paper was tacked to the surface of the table; and lengthwise along the top of the paper a heavy pencil line was drawn with UNPLEASANT printed in large letters at the left end of the line, PLEASANT at the right end. The cards were $3'' \times 5''$, white filing cards. The words were typed in the center of the cards. The cards were always stacked in a random order, and were shuffled several times in sight of the subject. The following were the 10 Japanese words used:[2]

I—warui
II—mushi
III—tori
IV—yoi
V—heiwa
VI—kenasu
VII—karai
VIII—tatakai
IX—homeru
X—amai

The Roman numeral accompanying each word will be used hereafter to symbolize the word.

While the subject was ranking the words, the experimenter retired to the other end of the room, behind a large screen which shielded all but the aperture of a memory drum from view.

(2) *Ranking the 10 English Words.*—As he collected the cards of the previous sorting from the table, the experimenter placed another shuffled pack before the subject, saying: "Will you please do the same with these?" These cards contained the English equivalents of the preceding set of Japanese words. The details of this step in the procedure were the same as those of (1). The primary purpose of this ranking was to disrupt the subject's memory of his ranking of the Japanese words. Also it was hoped that this additional element in the procedure would increase the subject's confusion as to the purpose of the experiment.

(3) *The Learning Situation.*—Immediately after ranking the English words, the subject was seated before the dark gray screen at the other end of the room and given the sheet of directions for learning. These directions were as follows:

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[2] These Japanese words were obtained from an article by Tsuru, S., and Fries, H. S., A problem in meaning, *J. Gen. Psychol.*, 1933, **8**, 281–284.

INSTRUCTIONS

Now the 10 Japanese words are going to appear one at a time in the little window before you.

You do not have to learn these words. What you do have to learn is which ones to pronounce when they appear and which ones to ignore when they appear.

The bell on the stand at your left will ring each time you make an error. There are two ways in which you can make an error: (1) by pronouncing a word that is not supposed to be pronounced, and (2) by failing to pronounce a word that is supposed to be pronounced.

Of course, the bell will ring often at the beginning. But in the end, when you are pronouncing only those words which are supposed to be pronounced, the bell will remain silent. You should thus strive to keep the bell as silent as you can. People can hear this bell all over the fourth floor.

A word is to be pronounced only while it is in the window. You do not learn the words by heart—you simply pronounce them or not as they one by one pass the window.

Each word will remain several seconds in the window. However, you should make up your mind as to whether or not you are going to pronounce a word as soon as it appears.

Pronounce the words in a loud voice. Do not worry over the correct pronunciations—none of us knows them—just do your best.

You have finished when you can keep the bell silent 5 successive times through the list—that is, 5 trials in which you pronounce only the correct words.

You must find out for yourself how many of the words are to be pronounced. Please do not question the experimenter.

You may keep these instructions to glance at between trials, when the window is blank.

Say when you are ready to begin.

The gray screen was 70½″ high and 52″ wide. A 13″ × 11½″ rectangular opening immediately in front of the subject exposed one side of an electrically operated, Chicago memory drum. From the subject's angle of vision he could see nothing on the other side of the screen. The subject observed the words through a ½″ × 1½″ opening in the metal shield of the memory drum. He was allowed to adjust as he pleased a gooseneck reading lamp which rested on a stand at his left. An adjustable stand at his left held the large bell about 10″ from the average subject's ear. The subject's freedom of movement in the chair enabled him to increase this distance to about 2′. The bell was wired into a single-make circuit and thus emitted with each closing of the circuit a single, gong sound. The metal saucer of the bell was 6″ in widest diameter.

In Experiment I the 5 words a subject was to pronounce were determined by his own preceding ranking. Each subject learned to pronounce the 5 Japanese words he had ranked in the lowest 5 positions (1–5). Thus the problem each subject faced in the learning situation was that of learning to pronounce only those 5 words which were for him the least pleasant of the 10.

When the subject signified that he was ready, the experimenter, who was seated on the other side of the screen, started the drum by closing the switch. Each word remained in the window for 6 seconds. When the subject's response (of either pronouncing or remaining silent) was in error, the experimenter sounded the bell with a finger key while the word was still in the window, 4½ seconds after its appearance. Thus the subject was given 4½ seconds in which to decide on his response. The

experimenter controlled this interval by watching the arm, attached to the motor shaft, which contacted the pins in the drive wheel of the drum. When the arm touched a thin metal marker fixed in its circular pathway, the experimenter pressed the key.

An interval of 18 seconds elapsed between trials. The order in which the words appeared was rotated from trial to trial between 3 arrangements. In the following diagram of these 3 fixed orders, the symbols of the words are used in place of the words themselves.

ORDERS

(1)	(2)	(3)
II	X	VI
V	IV	VII
VII	IX	VIII
I	VIII	II
VI	V	IV
III	VI	X
VIII	I	III
X	VII	IX
IV	III	V
IX	II	I

(4) *Second Ranking of the Japanese Words* (R_2).—Immediately after the fifth perfect trial in succession, the subject ranked the Japanese words under the same circumstances as before, with the exception of the directions. This time, as he placed the pack of cards on the table, the experimenter merely said, "Will you please line these up now with the most unpleasant at the left?" The experimenter was carefully noncommittal regarding the question of whether or not the subject should try to rank the words in the same positions he had put them in the first time. Thus such expressions as "in the same way," "as you did before," etc., were avoided.

(5) *Second Ranking of the 10 English Words.*—The subject then ranked the 10 English words in the same manner as that described above under (2).

(6) *The Mimeographed Questionnaire.*—Lastly, the subject was given a questionnaire sheet and asked to answer the questions by filling in the spaces left for each question. This questionnaire sheet consisted of the following directions and questions.

QUESTIONS

Please do not question the experimenter about the meaning of these questions or your answers. Do your best with them.

(1) When you were ranking the Japanese words the second time, did you remember the order in which you put them the first time?

(2) Were you inclined on the second ranking to place the Japanese words in the same positions in which you placed them the first time?

(3) Did you have any trouble judging the pleasantness or unpleasantness of the Japanese words—that is, did you have a hard time telling which words you liked and which you disliked:

(*a*) on the first ranking?
(*b*) on the second ranking?

(4) Can you give some idea of what the basis of your first judgments of the Japanese words was? For instance, pleasant or unpleasant sound might have been a basis; or the basis might have been that the words reminded you

of pleasant or unpleasant things. What was your basis in the beginning of the experiment? Illustrate with particular words.

(5) What was your basis of judgment when you ranked the Japanese words the second time, at the end of the experiment?

The 61 subjects used in this experiment were drafted in a random fashion from the writer's freshman and sophmore classes in psychology. Forty-six of them were males; 15 were females. None of them was informed concerning the true nature or purpose of the experiment. A sitting seldom lasted over an hour. Each subject was used for only one sitting and was requested at the end not to discuss the experiment with other members of the class.

II. Procedure of Experiment 2

Experiment 2 was designed as a control for Experiment 1. Each subject was put through steps (1), (2), (4), and (5) described above with an interval of time between (2) and (4) which was judged by the writer to be approximately equal to the average time taken with the third step in Experiment 1. It is necessary only to outline the steps of this procedure, since all details were the same as those of Experiment 1.

(1) *R_1 of the 10 Japanese words.*

(2) *First ranking of the 10 English words.*

(3) *One half-hour interval of rest.*—This interval was filled with the taking of Thurstone's Personality Schedule. If a subject had not finished the personality test when the half-hour was up, he was allowed to finish after the experimental sitting was over.

(4) *R_2 of the 10 Japanese words.*

(5) *Second ranking of the 10 English words.*

Sixty subjects, 33 men and 27 women, were used in this experiment.

III. Results of Experiments 1 and 2

Since the immediate concern of this paper is with the influence on relative affective value of a learning problem in which the subject is forced to pronounce 5 of the words, only the first and second rankings of the Japanese words (R_1 and R_2) in the 2 experiments and the questionnaire data of Experiment 1 will be treated. The following measurements obtained from the learning records of Experiment 1 will suffice to indicate the relative seriousness of the problem the subjects faced in the learning situation. The mean number of trials to learn, exclusive of the 5 final perfect trials, was 10.08 and the mean number of errors, 27.25. The respective sigmas of these means are .88 and 2.82.

(1) *R_1 of the 10 Japanese Words in the 2 Experiments.*—As far as R_1 is concerned, the conditions of the 2 experiments are the same. Table I shows for the 2 experiments separately the frequency with which each word was given each rank in R_1.

Each row in this table tells the number of times the word symbolized at the left was put in the rank positions at the top of the columns. In recording a subject's ranking, the word at the unpleasant extreme was given the rank of 1, the word at the pleasant extreme, the rank of 10. The mean rank orders presented in the second and third columns of Table II were derived from the figures of Table I after converting the latter

TABLE I

THE NUMBER OF TIMES EACH WORD WAS GIVEN EACH RANK IN R_1

Experiment 1

Words	1	2	3	4	5	6	7	8	9	10
I.....	14	15	12	5	6	5	3	0	0	1
II.....	17	13	8	6	2	5	1	3	4	2
III.....	3	9	11	9	5	5	8	2	6	3
IV.....	11	6	2	4	5	5	9	4	8	7
V.....	9	2	6	7	5	9	9	7	4	3
VI.....	0	2	9	11	13	11	6	1	4	4
VII.....	3	2	6	4	12	4	9	12	7	2
VIII.....	3	2	4	5	11	3	8	9	7	9
IX.....	1	7	3	7	2	7	4	11	13	6
X.....	0	3	0	3	0	7	4	12	8	24

Experiment 2

Words	1	2	3	4	5	6	7	8	9	10
I.....	14	7	7	7	8	7	3	2	3	2
II.....	9	12	13	6	5	6	3	2	4	0
III.....	9	12	4	5	6	5	7	3	6	3
IV.....	9	5	5	5	9	6	6	9	4	2
V.....	3	7	6	4	6	10	6	6	4	8
VI.....	5	3	6	10	5	6	6	7	8	4
VII.....	1	5	7	6	9	7	9	9	5	2
VIII.....	9	4	5	7	5	3	8	5	10	4
IX.....	1	3	3	7	4	7	6	7	11	11
X.....	0	2	4	3	3	3	6	10	5	24

into total rank orders. In the same space with each mean a number in parentheses indicates the rank order of the mean. Rank order correlation between these 2 columns of means yields a rho of .81. This coefficient may be taken as an indicator of the extent of agreement in mean ranks to be expected from a comparable group ranking under comparable conditions. Column 4 of Table II shows the mean rank orders of the 10 Japanese words derived from the composite R_1 rankings of both experiments. The rank order of these means may be

taken as that most likely to occur with a similar group of subjects in their ranking previous to experience with the words.

Although median rank orders have been calculated for all rankings discussed in this paper and found to be in close agreement with the means, only the means will be used in presenting pooled measures. The means have been chosen as the measure of central tendency on the assumption that with these materials the intervals between all rank orders are approximately equal. Since the 10 Japanese words undoubtedly cover only a narrow range of affectivity in the neighborhood of indifference, this assumption seems plausible.

TABLE II

THE MEAN RANK ORDERS OF EACH OF THE JAPANESE WORDS, IN VARIOUS RANKINGS, AND THE RANK ORDERS OF THE MEANS

Words	Mean Rank Orders					
	Exper. 1 R_1	Exper. 2 R_1	Exper. 1 and 2 R_1	Exper. 1 R_2	Exper. 2 R_2	Exper. 3 R_1
I.....	3.13 (1)	4.05 (2)	3.59 (1)	3.67 (1)	3.97 (2)	5.03 (5)
II....	3.57 (2)	3.83 (1)	3.70 (2)	4.67 (2)	3.90 (1)	5.57 (6)
III...	4.93 (3)	4.70 (3)	4.82 (3)	5.08 (4)	4.68 (3)	6.46 (9)
IV....	5.52 (6)	5.08 (4)	5.31 (4)	4.98 (3)	5.03 (4)	6.10 (7)
V.....	5.30 (4)	5.78 (8)	5.54 (5)	5.54 (5)	5.97 (8)	6.74 (10)
VI....	5.44 (5)	5.67 (6)	5.55 (6)	5.72 (7)	5.52 (6)	4.76 (2)
VII...	6.02 (7)	5.72 (7)	5.87 (7)	5.59 (6)	5.88 (7)	4.23 (1)
VIII..	6.44 (8)	5.48 (5)	5.97 (8)	6.36 (9)	5.37 (5)	5.00 (4)
IX ...	6.51 (9)	6.88 (9)	6.69 (9)	6.21 (8)	6.87 (9)	4.90 (3)
X....	8.13 (10)	7.80 (10)	7.97 (10)	7.16 (10)	7.82 (10)	6.21 (8)

(2) *R_2 of the 10 Japanese Words in the 2 Experiments.*—The mean R_2 ranks of Experiments 1 and 2 are presented in the fifth and sixth columns of Table II. The series of R_2 means of Experiment 1 are in fairly close agreement with the R_1 means, indicating that the intermediate learning had little effect upon the mean rank orders of the words. The rank order of the R_2 means of Experiment 2 are in perfect agreement with the rank order of the R_1 means. For the present purpose, namely, that of determining the influence of learning to pronounce 5 words and not to pronounce the other 5, these figures in columns 5 and 6 of Table II are not the significant ones, because in Experiment 1 every subject was not required to react in the

same way during the intermediate learning to any particular set of the words. Each subject was required to pronounce the 5 words which he himself had previously ranked lowest (in positions 1–5) in value; and this set of 5 words was seldom the same for 2 subjects.

(3) *Relationship between the Changes in Ranking of the Japanese Words (R_1 to R_2) and the Original Rank Orders (of R_1).*—For the present purpose the significant treatment of the data should relate the changes in rank order to the particular original rank orders, since the latter were the determinants of whether or not a subject was required to pronounce a word during the intermediate learning. In Table III are tabulated for Experiments 1 and 2 separately the numbers of times all words of a particular ranking in R_1 were given particular rankings in R_2. The second row of figures in this table reads: of all the words ranked 1 in R_1, 26 were ranked 1

TABLE III

THE NUMBER OF TIMES ALL WORDS OF A PARTICULAR R_1 RANK WERE GIVEN EACH RANK IN R_2

Experiment 1

R_1	1	2	3	4	5	6	7	8	9	10
1	26	11	5	3	3	4	6	0	1	2
2	8	16	13	3	3	2	3	4	6	3
3	5	10	13	6	7	4	5	3	3	5
4	5	4	6	9	6	8	5	8	10	0
5	1	2	3	9	9	10	8	8	6	5
6	5	7	9	7	12	9	4	6	1	1
7	2	4	3	7	7	9	17	4	3	5
8	1	2	3	8	5	9	8	14	8	3
9	4	2	3	6	6	3	5	9	14	9
10	4	3	3	3	3	3	0	5	9	28

Experiment 2

R_1	1	2	3	4	5	6	7	8	9	10
1	46	5	3	2	2	1	0	1	0	0
2	5	31	14	2	3	2	3	0	0	0
3	4	12	16	12	9	3	1	3	0	0
4	0	7	14	12	12	6	5	1	2	1
5	3	2	4	14	21	10	3	1	1	1
6	2	1	2	9	7	23	6	6	4	0
7	0	0	2	5	3	9	26	10	4	1
8	0	1	2	2	2	3	12	29	7	2
9	0	1	3	2	0	3	3	6	36	6
10	0	0	0	0	1	0	1	3	6	49

in R_2, 11 were ranked 2, 5 were ranked 3, and so on. Three sets of average measurements have been derived from the figures presented in Table III.

(*A*) One set of measurements, the mean rank orders in R_2 of all words receiving the same ranking in R_1, is shown in Table IV. In the second and fourth columns of this table are the means, and in parentheses their rank orders, for Experiment 1 and Experiment 2. The R_2 means for Experiment 2 show very little variation from the original rank orders. Those for Experiment 1 show a consistently greater variation and one which is in every case in the direction to be expected on the basis of the hypothesis that learning to pronounce a

TABLE IV

THE MEAN RANK ORDER IN R_2 OF ALL WORDS OF THE SAME R_1 RANK

R_1	Mean Rank Order in R_2		
	Experiment 1	16 *S*'s of Experiment 1	Experiment 2
1	3.03 (1)	4.56 (2)	1.62 (1)
2	4.18 (2)	5.69 (6)	2.75 (2)
3	4.64 (3.5)	5.94 (8)	3.63 (3)
4	5.48 (5)	6.56 (9)	4.52 (4)
5	6.21 (7)	6.94 (10)	4.80 (5)
6	4.64 (3.5)	3.88 (1)	5.75 (6)
7	5.97 (6)	4.81 (3)	6.72 (7)
8	6.48 (8)	5.25 (4)	7.38 (8)
9	6.75 (9)	5.69 (6)	8.17 (9)
10	7.62 (10)	5.69 (6)	9.67 (10)

word raises its affective value, and learning not to pronounce a word lowers its affective value.

(*B*) The second set of measurements consists of a single figure for each experiment, namely, the percentage of all words changing rank order (from R_1 to R_2) which moved in the direction to be expected on the basis of the hypothesis that those words the subjects learned to pronounce increased in affective value and those they learned not to pronounce decreased in affective value. It should be remarked that words of rank 1–5, R_1, were pronounced and those of 6–10, R_1, were not pronounced. This measure takes into account only the *direction* moved by words, and not the distance or number of ranks moved. The upper half of Table V presents

the percentages for both experiments. This table shows (1) the total number of cases of words changing rank in the 2 experiments; (2) the number of words changing in the direction to be expected on the basis of the hypothesis; (3) the percentage of words changing according to expectation; (4) the standard error of the percentage; (5) the difference between the 2 percentages for the 2 experiments; (6) the sigma of the difference; and (7) the critical ratio of the difference.

(*C*) The third measurement is the percentage of the distance (in terms of rank orders) moved, by words changing

TABLE V

TWO PERCENTAGE MEASUREMENTS FOR EXPERIMENTS 1 AND 2 OF THE CHANGE IN RANK ORDER—R_1 TO R_2—ACCORDING TO EXPECTATION

(1) *Number of Words Changing Rank*

	N	According to Expectation			Difference in Percent		
		N	Percent	σ_P	*D*	σ_D	D/σ_D
Experiment 1	455	358	78.7	1.9	14.4	3.3	4.4
Experiment 2	311	200	64.3	2.7			

(2) *Number of Rank Orders Moved by Words*

	N	According to Expectation			Difference in Percent		
		N	Percent	σ_P	*D*	σ_D	D/σ_D
Experiment 1	1348	1195	88.6	0.9	15.4	2.0	7.7
Experiment 2	600	439	73.2	1.8			

rank, in the direction to be expected on the basis of the hypothesis. This measure takes number of ranks moved as well as direction moved into account. The lower half of Table V contains figures for this percentage corresponding to the ones presented in the upper half for the other percentage.

These last 2 measurements leave no doubt concerning the existence of a real difference in the changes in rank order, R_1 to R_2, in the 2 experiments. There is doubt to be entertained, however, concerning the significance of this difference, because of a limitation of the rank order method. This method by its

nature favors changes in rank order of the same kind as those to be expected on the basis of the hypothesis in question. Therefore, before any measure of change in rank order is interpreted as being caused by a factor other than chance variation it must be shown to be reliably different from the measure predicted on the basis of chance. The magnitude of measures (*B*) and (*C*) to be expected on basis of chance can be easily calculated.

(4) *Percentage Measurements (B) and (C) to be Expected on a Basis of Chance Variation in Ranking.*—This percentage for (*B*) is equal to 70/90 (number of possible ranks above ranks 1–5 and below 6–10 over all possible ranks above and below both 1–5 and 6–10) or 77.8. The percentage for (*C*) is equal to 290/330 (number of possible ranks to be moved above ranks 1–5 and below 6–10 over all possible ranks to be moved above and below both 1–5 and 6–10) or 87.9. Both of these chance measurements lie within the range of the standard error of the corresponding percentages for Experiment 1, which are respectively 78.7 and 88.6.

Thus the outcome of the comparison of the changes in rank order obtaining in the 2 experiments, as far as permissible conclusions are concerned, is only one: that undoubtedly there is greater variation between R_1 and R_2 in Experiment 1 than in Experiment 2. Yet the possible truth of the hypothesis under investigation is not excluded. It may be that the predicted effects of the learning situation are present but masked by the increased variation.

There are 2 possible explanations of the chancelike magnitude of the percentages (*B*) and (*C*) in the data of Experiment 1. (1) The intermediate learning may simply have operated to increase the variation of all subjects' rankings in R_2. This interpretation would exclude any influence such as the one assumed by the hypothesis. (2) Or, the subjects may fall into 2 classes in terms of the effect the learning situation had on their R_2. The majority of subjects may have been unaffected by the assumed influence; but their R_2 was simply more variable than it would have been without the intermediate learning. These subjects would be accounted

responsible for the extreme variations in direction opposite to that of expectation. The remaining, smaller group of subjects may have reacted according to the hypothesis and would include those subjects accountable for the extreme variations in ranking in the direction predicted on the basis of the hypothesis.

(5) *The Answers Given by the 61 Subjects of Experiment 1 to Questions 1 and 2 of the Questionnaire.*—For the exact wording of these 2 questions the reader may refer above to the section on procedure of Experiment 1. These 2 are the only questions in the questionnaire which bear on the existence of a factor or factors possibly counteracting the hypothetical effect of the learning situation. The first question asks for a report of the presence or absence of the *memory of* R_1 *during* R_2. The second question asks for a report of the presence or absence of a *conscious attempt to reproduce* R_1 *in* R_2. The presence or absence of either of these is indicated respectively by a positive or negative answer to the question. The answers received and their frequency of occurrence are shown in the first 2 rows of Table VI. All answers such as 'in part,' 'to

TABLE VI

THE FREQUENCIES OF CERTAIN ANSWERS GIVEN TO THE FIRST THREE QUESTIONS OF QUESTIONNAIRE IN EXPERIMENT 1

Question No.	Frequency of Answer		
	Yes	No	'In Part'
(1)	7	23	31
(2)	27	31	3
(3a)	33	28	
(3b)	18	43	

some extent,' or 'only the extremes,' were considered identical and their frequency given in the third column of Table VI. In the group comparisons made below, these answers are considered positive ones.

The first and second columns of the upper half of Table VII present the number of subjects in all possible groupings based on answers to both questions 1 and 2. The third

column of this table presents an average measurement obtained from the records of each group, namely, the mean number of words, per subject, ranked in positions 1–5 in R_1 and in 6–10 in R_2. This is merely one way of measuring the average degree of the tendency to invert the ranking of words in the 4 groups. The lower half of this table presents the differences between the mean of any one group and those of all other groups, the sigmas of these differences, and the critical ratios.

Comparison of the means presented in Table VII indicates the following. (1) A highly reliable difference between the

TABLE VII

THE MEAN NUMBER OF WORDS, PER *S*, RANKED IN POSITIONS 1–5 IN R_1 AND IN 6–10 IN R_2 BY DIFFERENT GROUPS OF THE SUBJECTS OF EXPERIMENT I

Basis of Grouping Being Answers to Questions (1) and (2)

S's Answering	*N*	*M*	σ_M
A. Negative to both (1) and (2).....	16	3.06	.39
B. Positive to both (1) and (2).....	23	1.22	.16
C. Negative to (1); positive to (2).....	7	1.71	.39
D. Positive to (1); negative to (2).....	15	2.00	.38

Comparison of the Above Means

Comparison	Difference	σ_D	D/σ_D
A–B.....	1.84	.42	4.38
A–C.....	1.35	.55	2.45
A–D.....	1.06	.54	1.96
B–C.....	− 0.49	.42	1.17
B–D.....	− 0.78	.41	1.90
C–D.....	− 0.29	.54	0.54

mean number of inversions in rank for the group reporting the presence of both (*a*) memory of R_1 and (*b*) conscious attempt to reproduce R_1, and the mean for the group reporting absence of both factors (*cf. A–B*). (2) A strong probability that the true mean number of inversions for either group reporting the presence of (*a*) or (*b*) alone is less than that of the group reporting the absence of both (*cf. A–C* and *A–D*). (3) A strong probability that the true mean of the group reporting the presence of both (*a*) and (*b*) is less than that of either group reporting the presence of one alone (*cf. B–C* and *B–D*).

(4) There is very little evidence of a difference between the 2 groups reporting the presence of either (*a*) or (*b*) alone (*cf. C–D*).

The nature of the differences between these 4 means is consistent with the comprehensible conclusion that subjects are influenced in R_2 by the memory of R_1, although they report not trying to reproduce R_1, and that when they report a conscious attempt to reproduce R_1, as well as the memory of R_1, the influence of R_1 counter to the hypothetical effect of the learning situation (as evidenced by diminished number of inversions) is greatest. The 16 subjects reporting the absence of both (*a*) and (*b*) are as a group most likely to show the unadulterated effect of the intermediate learning process.

(6) *Relationship between the Changes in Ranking of the Japanese Words (R_1 to R_2) and the Original Rank Orders (of R_1) —as Evidenced by the 16 Subjects of Experiment 1 Who Answered Questions 1 and 2 in the Negative.*—Column 3 of Table IV contains the mean R_2 rank orders for this group of all words receiving the same rank order in R_1. These means diverge much more widely from the control means in column 4 than do the means for all subjects of Experiment 1 (in column 2). The means for the 16 exceptional subjects show a tendency to rank highest in R_2 the 5 words ranked lowest in R_1. And at the same time that the set of words ranked highest and the set ranked lowest in R_1 are inverted in R_2, the members of each set tend to maintain with respect to each other the same relative affective values.

Table VIII presents for these 16 subjects the 2 percentages, (*B*) and (*C*), corresponding to those presented in Table V for

TABLE VIII

TWO PERCENTAGE MEASUREMENTS OF THE CHANGE IN RANK ORDER—R_1 TO R_2—ACCORDING TO EXPECTATION; 16 SUBJECTS OF EXPERIMENT 1

	N	According to Expectation			Percent to Expect from Chance Variation
		N	Percent	σp	
(1) Cases of words changing rank	151	131	86.8	2.8	77.8
(2) Cases of ranks moved by words	546	508	93.0	1.1	87.9

all subjects. These 2 percentages are derived from the 2 rankings of the subjects, and are 2 ways of stating the relative amount of change in rank order which accords with the hypothesis. The last column of figures in Table VIII presents for comparison the 2 percentages to be expected on a basis of chance variation. It is to be remarked that for these 16 subjects the figure for chance, in the case of both (*B*) and (*C*), lies several times the distance of the standard error from the experimentally obtained percentage and on that side of the latter which yields a difference favorable to the hypothesis.

It may be concluded, therefore, that (1) there exists an influence of R_1 on R_2 which works through memory or memory and conscious attempt to reproduce the original ranking, and which results in some subjects failing to show the the predicted influence of the learning situation; and that (2) those subjects who report the absence of both memory of R_1 and conscious attempt to reproduce the original ranking exhibit a tendency to change the relative affective values of the words in a manner which is in accord with the hypothesis.

(7) *The Answers of the 61 Subjects of Experiment 1 to the Remaining Questions of the Questionnaire.*—The number of subjects giving positive and negative answers to questions 3*a* and 3*b* may be found in the third and fourth rows of figures of Table VI. These figures indicate that the subjects experienced greater difficulty with R_1 than with R_2. This is a significant fact in that it implies that the intermediate learning process made the ranking of the words easier, an effect to be expected if the learning process was to influence the affective values of relatively indifferent objects.

In answer to the last 2 questions of the questionnaire the majority of the subjects did little more than indicate their basis or bases of judgment by a single word or phrase. They seldom gave concrete illustrations. The only 2 illustrations that occurred with any considerable frequency were meaningful associations with 'amai' and with 'mushi.' The first was connected with the Latin word for 'friend'; the second was connected with the English word 'mush.' In itemizing below the various bases of judgment given, each basis is accompanied by a number which indicates its frequency of occurrence.

The following answers were given to question 4, which asked for the bases of judgment in R_1: (1) sound—35, (2) meaningful association—47, (3) appearance of the word—7, (4) relative ease of pronunciation—4. The value of these answers is marred by the unknown suggestive influence of mentioning sound and meaning in the wording of the question.

The answers to question 5, relevant to basis of R_2, were more varied. The following were given without any reference to the learning situation: (1) sound—25, (2) meaningful association—26, (3) ease of pronunciation—2, (4) attempt to make R_2 the same as R_1—9. The following influences of the learning process on judgments in R_2 were listed: (1) increased familiarity changed judgments—6, (2) those words to which there was difficulty in learning the proper reaction became unpleasant—19, (3) those words which had to be pronounced became more pleasant and vice versa for those not pronounced—3, (4) a clearer idea obtained of the sound of the words resulted in changing judgments—1, (5) awareness of the impulse to pronounce words resulted in judgment that they were pleasant—1.

EXPERIMENT 3

I. Procedure

Experiment 3 was designed to produce data which would make it possible to estimate the effect of the learning situation on affective value, exclusive of any effect of previous judgments by subjects of the affective value of the objects. The subjects in this experiment, therefore, did not rank the words before learning; their first attempt to rank came immediately after learning. Comparison of the mean rankings of this group and the first rankings of the groups of subjects of Experiments 1 and 2 should reveal the desired effect. The subjects were put individually through the following steps, in which all details not mentioned were identical with those of Experiment 1.

(1) *The learning situation.*—As soon as the subject entered the experimental room he was seated before the screen and memory drum and given the instructions for learning. Every subject was required to pronounce the same 5 of the Japanese words. These 5 were the ones symbolized above by the Roman numerals I–V, and which were given the lowest affective ratings in the composite mean R_1 orders of Experiments 1 and 2.

(2) *Ranking the 10 Japanese words in order of preference.*—Immediately after completion of learning the subject was taken to the table and given the instructions for ranking and the shuffled pack of cards.

(3) *Ranking of the 10 English words.*

(4) *The mimeographed questionnaire.*—The questionnaire each subject was asked to fill out before leaving contained the following directions and questions.

QUESTIONS

Please do not question the experimenter about the meaning of these questions or your answers. Do your best with them.

(1) Was the ranking of the Japanese words easy?

(2) Were you fairly certain of your judgment of relative pleasantness or unpleasantness in most cases?

(3) Can you give some idea of what the basis of your judgments of pleasantness was? For instance, pleasant or unpleasant sound might have been a basis; or the basis might have been that the words reminded you of pleasant or unpleasant things. Illustrate with particular words if you can.

(4) Do you think your ranking of the Japanese words was in any way influenced by the preceding learning experiment? In what way?

Seventy subjects, 33 men and 37 women, were used in this experiment.

II. Results

The means of the 70 subjects' trials and errors to learn the initial problem to 5 perfect repetitions were, for trials, 9.90 and, for errors, 24.04, with the respective sigmas of .86 and 2.24.

(1) *Ranking of the 10 Japanese Words.*—Table IX shows the frequency with which each word was given each rank by

TABLE IX

THE NUMBER OF TIMES EACH WORD WAS GIVEN EACH RANK IN EXPERIMENT 3

Words	1	2	3	4	5	6	7	8	9	10
I.....	6	8	5	8	11	13	8	7	2	2
II.....	9	6	6	8	5	7	6	6	8	9
III.....	2	2	5	6	6	10	12	12	13	2
IV.....	7	6	5	6	6	2	8	10	9	11
V.....	3	4	4	3	6	7	10	11	13	9
VI.....	8	7	13	9	8	7	5	3	5	5
VII.....	11	16	7	5	8	8	3	7	3	2
VIII.....	13	5	9	7	4	8	6	5	8	5
IX.....	7	9	10	7	9	6	9	5	4	4
X.....	4	7	6	11	7	2	3	4	5	21

the 70 subjects. In the last column of Table II appear the mean rank orders of the words obtained with this group of subjects. These means and their rank orders in parentheses are to be compared with those in column 3, the composite means obtained from the pooled records of both Experiments 1 and 2, for appreciation of their divergence from the rank orders most likely to occur in a group of subjects prior to the learning situation. With the exception of one word (I), the 5 receiving before learning the 5 lowest average ranks receive,

after learning, the 5 highest average ranks. In this almost complete inversion of the pooled relative affective values, it is to be remarked that the members of each set of 5 words maintain approximately their same relative standing to each other. In other words, it is as if the upper and lower 5 words were fixed each on separate bars of an upright slide rule, and the learning resulted in the bars sliding toward and somewhat past each other, thus inverting the spatial relationship between the 2 sets of words. Rank order correlation between the mean rank orders of the words obtained in Experiment 3 with the means obtained in R_1 of Experiment 1 and Experiment 2 yields rhos respectively of $-.25$ and $-.07$.

(2) *The Mean Number of the Words Pronounced in Experiment 3 Ranked, per Subject, in the Upper 5 Positions (6–10).*— This measurement is analogous to the one used in comparison of the sub-groups of Experiment 1 and presented in the upper half of Table VII. Derivation of the measurement simply involved determining for each of the 70 subjects how many of the words I–V were given a ranking higher than 5. This number, of course, could not be less than 0 or greater than 5. After tabulating these numbers, the mean was extracted. For purpose of comparison the same treatment was applied to the R_1 rankings of Experiments 1 and 2 and to the R_2 ranking of Experiment 2. The means for all 4 of the rankings are presented in the upper part of Table X. The means for the 3

TABLE X

THE MEAN NUMBER OF THE WORDS I–V RANKED, PER SUBJECT, IN THE FIVE MOST P POSITIONS (6–10)

Ranking	M	σ_M
A. Experiment 1, R_1	1.85	.10
B. Experiment 2, R_1	1.95	.12
C. Experiment 2, R_2	1.98	.13
D. Experiment 3	2.96	.13

Comparison of the Above Means

Comparison	Difference	σ_D	D/σ_D
D–A	1.11	.16	6.94
D–B	1.01	.18	5.61
D–C	0.98	.18	5.44

rankings prior to learning do not differ greatly among themselves; the mean for the ranking after learning, however, diverges widely from the other 3. In the lower part of this table is presented the difference between the mean obtained in Experiment 3 and each of the 3 other means, the sigma of each difference, and the critical ratio.

From the comparisons made of the rankings in Experiment 3 and those made prior to learning in Experiments 1 and 2 it may be safely concluded that learning positive reactions to the one group of words and negative reactions to the other operates to raise the relative affective values of the former and to lower the relative affective values of the latter.

(3) *Answers Given by the Subjects to the Questionnaire.*—The frequencies of 'yes' and 'no' answers to questions 1, 2, and 4 are shown in Table XI. Judging from the preponder-

TABLE XI

THE FREQUENCIES OF ANSWERS GIVEN TO QUESTIONS (1), (2) AND (4) IN THE QUESTIONNAIRE OF EXPERIMENT 3

Question No.	Frequency of Answer	
	Yes	No
(1)	54	16
(2)	57	13
(4)	49	21

ance of answers in the affirmative to questions 1 and 2, the subjects of this experiment experienced less difficulty with their ranking of the Japanese words after learning than did the subjects of Experiment 1 in their ranking prior to learning (*cf.* the third row of Table VI). The majority of affirmative answers given to question 4 indicates that most of the subjects were aware of some influence of the learning process on their affective judgments.

The following answers were given, with the accompanying frequency, to questions 3 and 4 as bases of affective judgment other than any relevant to the learning process: (1) sound—41, (2) meaningful association—31, (3) appearance of the word—4, (4) ease of pronunciation—6, (5) a liking or disliking for certain letters—1. In the answers to questions 3 and 4 the following influences of learning were mentioned: (1) words pronounced

became more familiar and thus more pleasant—3, (2) difficulty in learning the proper reaction to a word made it unpleasant —30, (3) words pronounced became more pleasant—10, (4) pronouncing words aroused dislike for them—1, (5) recognition of the impulse to pronounce a word aroused the judgment that it was pleasant—1, (6) pronouncing words gave a clearer idea of their sound—2, (7) the active interest required by the learning influenced judgments—4, (8) words difficult to pronounce were unpleasant—2.

Summary and Discussion

The major concern of this paper has been with the modification of subjects' affective evaluations of a series of objects from a first to a second judgment, both within an hour, when interpolated between the 2 judgments was a learning situation in which the subjects were required to learn a positive reaction to half of the objects and a negative reaction to the remaining half. The use of the rank order method of measuring affective value has placed certain limitations on interpretation of changes of value apparent in the data of the 2 rankings. (1) In the first place, mean measures of changing affective value within the same group of subjects must be shown to be reliably different from those means which would accompany the effects of chance variation. (2) In the second place, any conclusions drawn concerning shifting affective value must be couched in terms of relative affective value of one or more of the objects to the other members of the group. Thus we have no basis upon which to fix a conclusion relevant to the absolute affective value of the whole group of objects or any of its members. (3) And a third limitation is that any demonstrated change in relative affective value of one set of the objects may be due either to a change in value of this set or to change in the remaining members of the whole group of objects. Rank order data offer no basis of choice between these alternatives, since the same modification of mean rank measurements would result from either change in affectivity.

In Experiment 1, 61 subjects ranked the 10 Japanese words, learned to react positively to the 5 ranked lowest, and then ranked the 10 words again. In control Experiment 2,

60 subjects merely ranked the 10 Japanese words twice with an interpolated rest interval of half an hour. Comparison of the shifts in average affective value (from the first to the second ranking) in the 2 experiments shows a reliable difference with the values shifting in the manner predicted on the basis of the hypothesis, *i.e.*, in Experiment 1 a much greater change of the lowest 5 words in the P direction and of the highest 5 words in the U direction. It cannot be concluded from this, however, that the hypothesis is verified, because the absolute amount of shifting present in the 2 rankings of Experiment 1 is practically identical with that to be predicted on a basis of chance variation in judgments. Thus just as valid as the conclusion that the hypothesis is verified by the data would be the conclusion that the intermediate learning in Experiment 1 merely results in reliably greater change in affective judgments.

Comparison of the results of Experiments 1 and 2 yields a difference to be interpreted as evidence of the hypothesis only when the subjects of Experiment 1 are grouped on the basis of their own testimony of the influence their first ranking had on their second. All but 16 of the subjects report awareness while making the second ranking of either one or both of (1) memory of the first ranking and (2) conscious attempt to make the second ranking of the objects the same as the first. The mean measurements of shift in rank order in the records of the remaining 16 subjects show changes reliably different from those which would result from chance. Therefore it may be concluded from Experiments 1 and 2 that the predicted effect of the learning situation occurs in a group of subjects but that when they have judged the items previously to learning this effect appears only in conflict with a tendency to maintain constant affective rating of the items.

The close agreement between the mean first rank orders of the 2 groups used in Experiments 1 and 2 offers a foundation for expecting similar mean rankings from a comparable group of subjects under the same conditions. Seventy subjects in Experiment 3 ranked the 10 Japanese words under conditions similar in all respects to those of the first ranking of Experi-

ments 1 and 2 save one, namely, they solved the learning problem prior to their first ranking. Mean measurements of the rankings of the words in Experiment 3 differ reliably from those of Experiments 1 and 2 and the difference is in the direction predicted on the basis of the hypothesis. This comparison is not hampered by the first of the 3 limitations to the rank order method listed above. Also the comparison of the mean first rank orders of Experiments 1 and 2 with those of Experiment 3 is not limited by the possible effect of a ranking only a few minutes prior to the ranking from which the means were derived. Therefore, Experiment 3 offers a second, and less ambiguous, evidence favoring the hypothesis under investigation. And it is apparent in the results of this experiment that the effect of learning positive reactions to one set and negative reactions to the other set of words operates in conflict with the same conditions which determine the first rankings of Experiments 1 and 2. This conclusion is drawn from the similar relative positions in both rankings (before and after learning) of the individual members of the 2 sets, one of which moved toward U as a whole in Experiment 3, the other toward P.

The use of Japanese words in these experiments limits any permissible conclusions to relatively indifferent objects. This is not necessarily to be taken as a weakness of the experiments, however, since a fair test of the hypothesis calls for the use of indifferent objects. Objects toward which adult human subjects already have definite affective attitudes have behind them years in which the determinants of affective judgments have been operating, and if the implications of these experiments be true, years in which positive and negative reactions have been learned to the objects.

The problem of explaining the effects demonstrated in the data presented herein has been purposely reserved for a future publication. The learning records of the subjects of Experiments 1 and 3 have not been considered. These records contain the number of times each subject actually did pronounce each word and the number of times each subject reacted erroneously (with the bell ringing) to each word. Examina-

tion of these data may answer the problem of whether the important determinants are positive and negative reactions, per se, or rather the undesirable effects of errors.

Description of these experiments would be incomplete without mention of the subjects' typical reaction to the bell. This turned out to be more than satisfying. In the preliminary planning of the experiment the bell was chosen as a mild reprimand for error. But during the experiments it became apparent to the experimenter that the bell was a relatively violent emotional stimulus, eliciting flinching movements from the subjects, overt exclamations of vexation, moving to the side of the chair opposite from the bell, and a tense waiting after each reaction for the verdict of that inanimate object. In their written reports many of the subjects mentioned the bell in conjunction with their statement of the probable influence on feeling tone of the difficulty experienced with certain words.

The subjects' written reports turned out to be of value in Experiment I in defining the influence of a previous ranking of the series of words upon a subsequent ranking. Besides this return on these reports there is also clear evidence of the greater ease of judging after learning than prior to and several hints as to the nature of operation of the learning situation in determining affectivity. Prominent among the latter is the frequently mentioned 'difficulty' experienced with some of the words and the reaction to be attached to it. This implies that the real determinant of the changes in affectivity found are the result of what is commonly known as 'effect' of reactions rather than the reaction itself.

The results of these experiments present precise statement of more questions by far than they do answers. The following are some of the more urgent of these problems. What is the true determinant of the effect on relative affectivity of the learning situation? Is it sheer repetition, favoring and disfavoring 'effects' of reactions, or possibly some reciprocal process such as facilitation and inhibition? The real determinants might be any combination of these alone or in conjunction with other unknown factors. Is the shift in

affective value due to the positive reactions to some words which accordingly gained or rather to the negative reactions to other words which lost in affective value? According to the present data either one or both of these factors might be operative. And, what of the absolute affective values of the words? Does the group as a whole gain or lose after the learning process? Besides these questions which grow directly out of the present method and results, there of course remains the systematic investigation of the relative importance of every detailed condition in determining the measured effects. Among these conditions there immediately occurs to mind the time interval between the learning situation and the estimate of affective value, the number of perfect trials required as the criterion of learning, the meaningful value of the objects judged, the nature of the 'effect' used in the learning situation, and the specificity of the instructional set given the subjects preliminary to their ranking of the affective values of the objects.

Conclusions

1. A learning situation in which objects are reacted to positively or negatively results in an increase in the pleasantness of those objects to which the reaction was positive relative to those objects to which the reaction was negative.

2. This tendency is masked, when the relative pleasantness of the objects is judged prior to learning, by an opposing tendency toward maintenance of the same relative affective judgments.

3. Even when this tendency shows itself it operates in conjunction with the unknown determinants of judgment prior to learning.

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THE CROSSED EFFECTS UPON VOLUNTARY MOVEMENT OF A UNILATERALLY INDUCED FATIGUE

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The variety of ways in which the term fatigue has been used not only in common speech but also in scientific writing necessitates considerable caution in the use of the concept. The term may be found to indicate decrements in muscular activity, raised sensory thresholds, adaptation, refractory states of nerve and muscle, reduced capacities for work either mental or physical, effects of accumulated toxins, sensations from overworked muscles, boredom, distractibility, and almost any unanalyzed hindrance to effective work. The term fatigue will be used in this discussion to denote a condition developed within the organism coincident with prolonged muscular activity which operates as a decrement either to the total movement or to components of that movement (*cf.* Ash, 1, p. 1). Precisely to distinguish fatigue from inhibition, adaptation and the like is not the purpose of the present experiments. Rather, the general purpose has been to study certain bilateral relationships of movement using fatigue, as defined above, in the role of a tool to aid in revealing those relationships. It has long been evident that the bilateral association of functions is one of the basic problems of the integration of the organism.

That changes in the centers of neural control following prolonged voluntary movement are responsible for most of the gradual decrements of such movement was inferred from experiments by Mosso (19), Waller (25), Lombard (17) and others. Their method consisted in direct electrical stimulation of the forearm muscles immediately following the repeated voluntary contraction of those muscles until exhaustion.

* This experiment was performed by the writer in the Department of Nervous and Mental Diseases, Northwestern University Medical School.

They found that even after the individual could no longer voluntarily contract the muscles against the ergographic weight, direct faradic stimulation of the muscles produced energetic contractions. Critics (**16**) claimed that the muscles stimulated directly were not the same as those innervated voluntarily, and that the myo-neural junction was the locus of much of the fatigue. Reid (**22**),Cattell and Stiles (**6**), and Walter (**26**) have recently shown that the myo-neural junction plays an insignificant role in decrements following successive contractions. Reid found that slow voluntary contractions carried to fatigue do not alter the amount of work a muscle may subsequently accomplish by peripheral stimulation but that rapid voluntary contractions to fatigue do bring about such alterations. He interpreted his work as implying that the centers of neural control played the major role in decrements of activity following prolonged voluntary contraction.

The experiments of Sherrington (**24**) and Forbes (**11, 12**) with spinal animals and of Fischgold and Bernard (**10**) with human beings reveal that spinal centers are very susceptible to fatigue. That there is an irradiation of both excitatory and inhibitory conditions in the cord has been implied from several experiments (**11, 12, 24**). It is important in relation to the present experiments to note that a condition recognized as fatigue may apparently produce either excitatory or inhibitory effects. Thus, Forbes, in a flexor preparation, applied one set of electrodes to the ipselateral peroneal nerve and another set to the ipselateral popliteal nerve. He found that

> stimulating one reflex arc even to the point of marked fatigue, instead of imparting some degree of fatigue to the allied reflex arc, actually improved the subsequent response of the latter (**11**, p. 114).

He observed, furthermore, that inhibition of a reflex through one nerve impaired subsequent inhibition through the same nerve but improved inhibition through the allied arc. Either excitatory or inhibitory conditions may, therefore, produce effects through what appears to be an irradiation of those conditions. Similar irradiated effects should also be found for the more complex levels of the nervous system; that is, for example, for the so-called voluntary movements.

The studies upon crossed effects in voluntary bilateral movements have been confined almost entirely to the problems familiarly known as transfer of training.[1] However, a few such studies not concerned with training have been made. Reports from neurological clinics have revealed interesting associations between the motor areas of the two cerebral hemispheres. Thus, it has been noted in some cases of hemiplegia that movements on one side will be followed by symmetrically opposite movements of the other side (**9**). Furthermore, in certain cases of the parkinsonian syndrome it has been observed that if the patient is attempting to perform the same movement with both arms simultaneously the less affected side will take on the characteristics of the more affected side (**7**). Nafe (**21**) has recently pointed out that many years ago Brown-Sequard found that when one hand was held in cold water vaso-constriction occurred not only in that hand but in the opposite as well.

Few experiments have dealt directly with crossed effects of fatigue. Bryan (**5**) found crossed effects of fatigue when symmetrically opposite joints were concerned. He observed that

> in every trial . . . extreme local fatigue in a joint was followed by a diminution in the rate of the corresponding joint on the opposite side, while other joints, upon both sides, showed no corresponding change in general motor ability (**5**, p. 149).

Joteyko (**14**) recorded ergographically finger contractions of the right hand following the dynamometric fatiguing of the left hand. With some subjects the crossed effect was augmentation; with others there was a decrement. She also took æsthesiometric measurements of skin sensibility following ergographic work. Increases or decreases in energy following a contralateral fatigue were accompanied respectively by increases or decreases of cutaneous sensibility. She suggests that there are basic or inherent differences in sensory-motor mechanisms which account for the findings.

Direct evidence in the literature of crossed effects upon voluntary movement of a unilaterally induced fatigue appears to be confined to these two foregoing experiments. The

[1] See Bray (**4**) for history of work on transfer of training.

purpose, therefore, of the present experiments was to study these crossed effects by more sensitive methods in order to determine more accurately their character and magnitude.

The research is conveniently divided into two parts. Part I presents data showing crossed effects upon rate and amplitude of voluntary pronation-supination subsequent to a prolonged similar movement on the opposite side. Part II is a study of these same effects upon the temporal character of the separate components of reciprocal movement.

Apparatus [2]

The apparatus permitted a direct transmission of rotary forearm movements (pronation-supination) to a kymograph drum. Records either of both arms simultaneously or of each individually are possible. A Joseph Becker time marker actuated by the 60 cycle city current gave time line units with a frequency of 120 per second. Slower rates were controlled by the Harvard direct current interrupter. Frequency for a given experiment was dependent upon particular requirements.

Part I

Method

In this part of the experiment four subjects participated, each making a series of twenty records (Subject *J*, 22 records). The height of the subjects in relation to the apparatus was adjusted so that the angle between forearm and upper arm was approximately 100 degrees. Only one set of records was taken on a given day. The subject grasped both handles. On odd numbered days he was instructed that following a signal 'Go' he should begin by reciprocally rotating, *i.e.*, pronating-supinating, the right arm as fast and as far as possible. At the signal 'Stop' the subject stopped the right arm movement, but began immediately to operate the left in the same manner. On even numbered days the left arm was operated first and the right immediately followed. Since no mechanical restrictions were introduced, the extent of the rotations under these conditions depended upon the anatomical and physiological characteristics of the subject's forearm and upper arm together with the dynamic relations of the total response pattern. Lateral movements of forearm and elbow, which might under other conditions become overflow movements (1) as fatigue developed, were eliminated by the character of the arm rest. The anatomical factors contributing to recorded rates and amplitude were constant for each subject throughout the series.

The work period for each arm was sixty seconds. This length of period was found to produce not only marked decrement in the objective records but, according to introspective reports, feelings of extreme fatigue. The twenty periods for each subject may be considered as giving ten cases of right arm operating first, or with no initial fatigue, and ten cases of right arm operating second, or following initial contralateral fatigue. There are also ten trials each for left arm first and left arm second. The behavior of each arm may be compared with itself under the two sets of conditions. Since the movement was unrestricted except by anatomical and functional conditions, it is possible to study not only modifications of rate of movement but of amplitude also.

[2] A detailed description of this apparatus may be found in Collier (7).

Results and Interpretation

1. *Effects of Contralateral Fatigue.*

The data from subjects *J* and *W* shown graphically in Figs. 1 and 2 are typical of the results of Part I. Graphs are based on rate and amplitude during only the first ten second

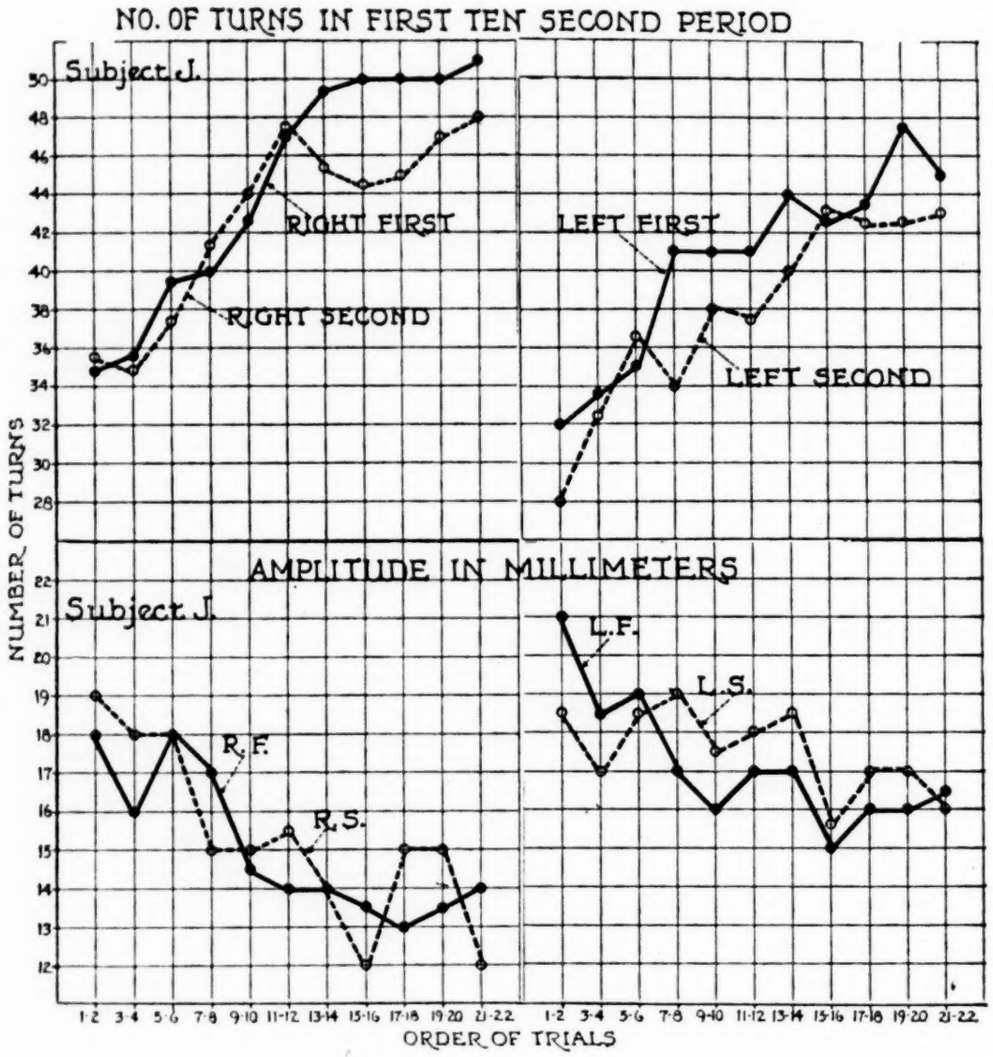

FIG. 1

period of each arm for the successive trials. In the upper quadrants frequencies of right and left forearm rotation are compared under the two conditions, namely (*a*) no initial fatigue; and (*b*) initial contralateral fatigue. The graphs indicate that a preceding contralateral fatigue operates slightly to reduce rate of subsequent movement on the opposite side. This observation holds only when rates of move-

ment are compared for the first ten-second periods. When later ten-second periods are compared no valid difference is indicated. This is taken to mean that the contralateral effects of a unilateral fatigue under the conditions of this experiment cease to be active sometime during the first ten seconds after the fatiguing movement is terminated.

In the lower quadrants the amplitude of movement in millimeters of tracing is represented graphically.[3] When each arm is compared with itself on the basis of preceding or succeeding the contralateral fatigue, it is found that the latter condition favors an increased amplitude of movement. There are more exceptions to this generalization than that concerning rate. Inspection, however, reveals that the broken line is more frequently above than below the solid line. This increase in amplitude is in direct contrast to the decrease in frequency of rotation noted in the upper quadrants. The method of Part II was designed primarily to study this contrast in more detail. The problem will be referred to again.

Figure 2 shows the data from the second subject (Subject *W*). The same general results are apparent. Subjects *K* and *C* gave similar sets of data.

2. *Effects of Practice.*

The general trend of the graphs of Figs. 1 and 2 is of interest. The twenty work periods for each subject gradually increased the frequency of turns per unit of time, but gradually decreased the average amplitude. Apparently the extent of rotation is sacrificed in favor of an increased rate. The instructions, however, were never varied. Each time the experimenter would say, "Now I want you to rotate your forearm as far each way and as fast as you can." As the subject attempted to realize his maximum effort, he was probably interpreting that maximum in terms primarily of speed. Introspective reports on this specific point would be significant. Such reports were not obtained since the relationship indicated is not apparent from direct observation of the

[3] Each millimeter of amplitude represented in the chart is equal to 8.7 degrees of arc of forearm rotation.

kymograph record and was revealed only after analysis several months later.

For the right arm, the increase in the number of turns throughout the experimental series is more than forty percent. There is also a comparable increase in the frequency of turns

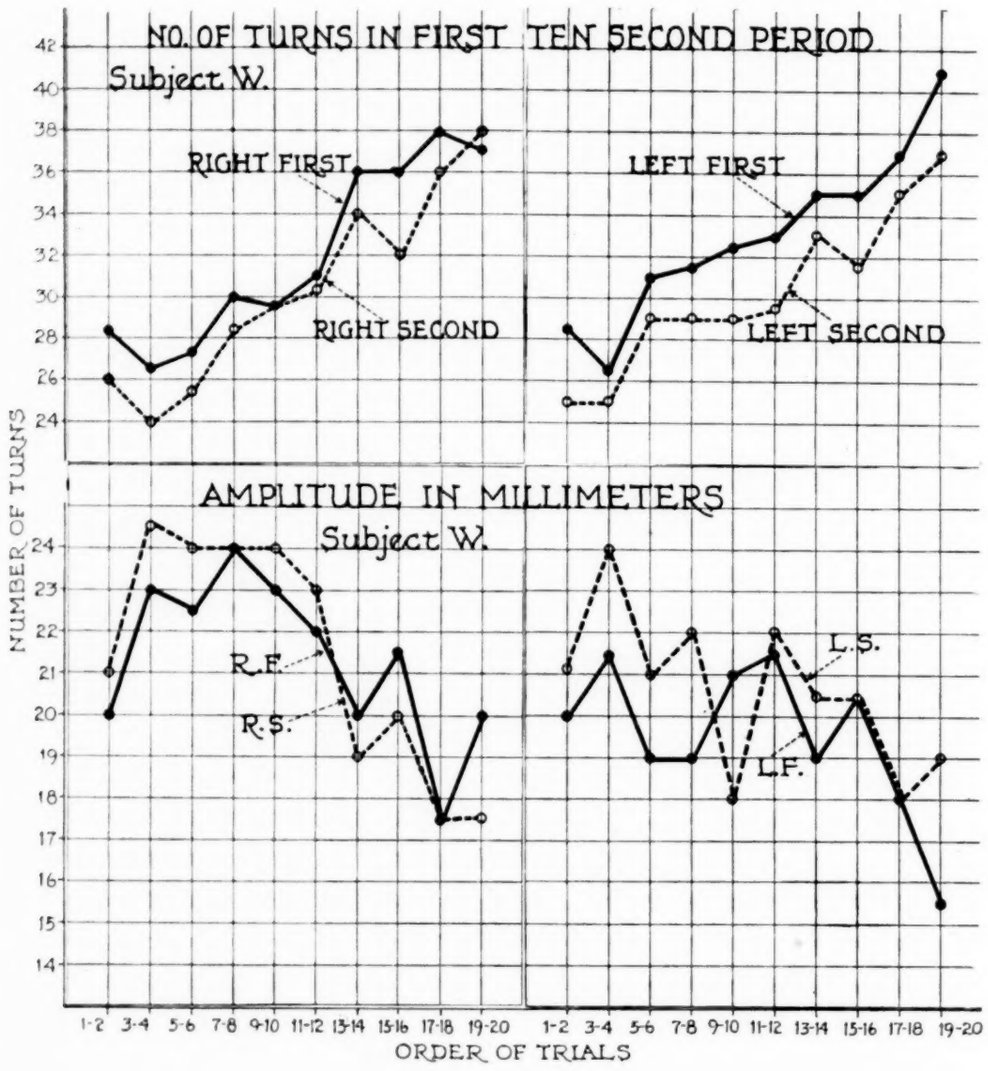

FIG. 2

for the left arm in the successive initial ten-second periods. The graphs appear to be the early phases of a curve of learning.

Since Figs. 1 and 2 indicate an increase of rate and a decrease of amplitude with successive trials, it is of interest to determine if there is any increase in total movement when the score is the product of both factors. The percentage curves

of Fig. 3 permit a direct comparison of both factors with their product when all three curves are made to rise from a common point of origin. With the first score for each curve as a base of reference, succeeding scores are represented as percentages of increment or decrement from the original. All curves, therefore, arise from zero and the reciprocal relationships between rate and amplitude become more

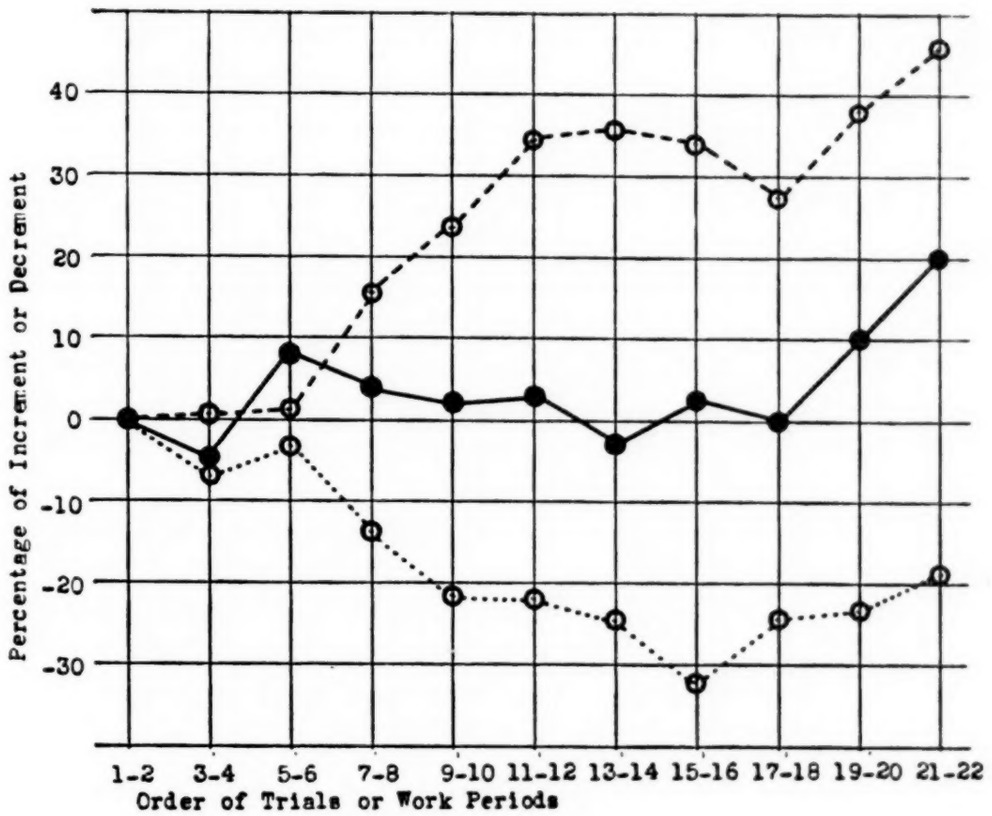

FIG. 3. (Subject *J*). Solid line—percentage curve for total movement. Dash line—percentage curve for rate of movement. Dotted line—percentage curve for amplitude of movement.

apparent. The curves are partially smoothed by averaging the values of each two successive occasions. There are, therefore, ten base line units instead of twenty. The increment in total movement is slight. There is evidence here of high stability in certain obscure dynamic factors controlling movement. The increment in one phase of the movement is balanced by a decrement in the reciprocal phase. The problem of the conditions under which rates of movement are increased with practice evidently need further investigation.

The tapping boards have never adequately controlled or recorded the factor of amplitude or the closely related factor of force of movement. The tapping frame only partly controls these same factors. Overflow movements of the operating hand or arm become apparent as the limits of the frame cut short a movement pattern whose neuromuscular dynamics seem to be adjusted for a larger range of execution. Neither the overflow movements nor the mechanically impeded aspects of the pattern are recorded. Under the conditions of the present experiment these overflow move-

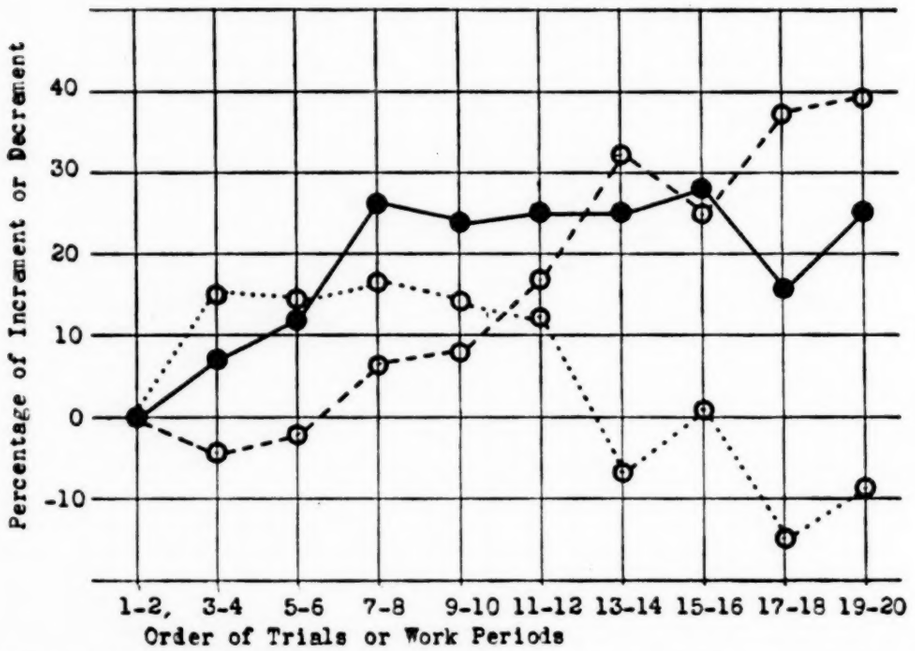

FIG. 4 (Subject *W*). Solid line—percentage curve for total movement. Dash line—percentage curve for rate of movement. Dotted line—percentage curve for amplitude of movement.

ments of the hand and arm are reduced to a minimum. Relative variations in force of movement, which with the tapping board or frame would be absorbed by a mechanical interference, are translated into variations in amplitude of rotation. These variations can be measured.

Figure 4 presents the same general relationships as Fig. 3, with the exception that there is a more definite increase in the scores representing total movement. Figures 3 and 4 are included to show that rate and amplitude of unrestricted movement are functions of different variables. The necessity of either controlling one or recording both is obvious.

3. *Effects of Homolateral Fatigue.*

Figure 5 is included to show the very rapid decrement in total movement over the sixty-second work period. The factors of rate or amplitude by themselves are not as sensitive to the effects of fatigue. The rate of decrement when the curve is a function of both factors combined is probably a more accurate indication of quantitative accomplishment than considering merely speed of movement as is done with the usual tapping devices. At the end of a two-minute tapping period the decrement is usually about 20 percent of the original rate (Wells, **28**; Whipple, **29**; Boder, **2**). Curves

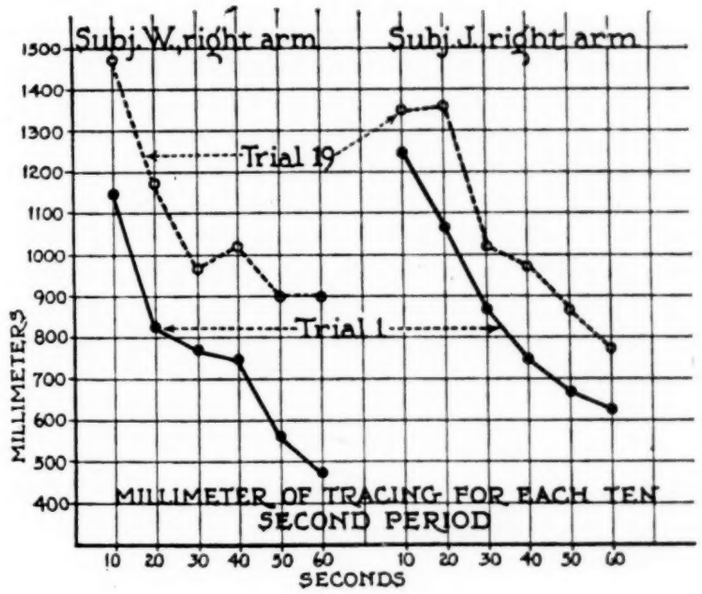

FIG. 5

of Fig. 5 show that at the end of a one-minute period (trial one) the decrement is approximately 50 percent when both rate and amplitude are factors. This is a significant point in technique if one is to study conditions producing increments or decrements of motor response.

Comparison is made between the first and nineteenth trials. An increase in resistance to decrement is indicated. This aspect of the results is similar to observations made by Glaze (**13**) and Robinson and Robinson (**23**) wherein they found not only increased rates of movement with practice but also an increased resistance to factors producing decrement.

PART II

Method

The data of Part I indicated a tendency for forearm rotations, subsequent to a contralateral fatigue, to have slightly reduced rates and slightly increased amplitudes. Since these data were not entirely conclusive, more sensitive and analytical methods were necessary. Recent work by Boder (2) on tapping suggested to the writer that a study of the four components of reciprocal movement would reveal more clearly the differences observed.

The same apparatus as in Part I was used with one exception. A mechanical restriction was introduced to limit the extent of rotation. The particular limit used in this case was arbitrarily set at 40 degrees.[4] The record obtained under these conditions with a rapidly moving drum appears like the following tracing. Without the restriction the crests and troughs are rounded. With the above tracing it is possible more accurately to determine the points of initiation and termination for each of the four components of reciprocal movement, *i.e.*, the two progressions and the two reversals. Time line units of 8.3 milliseconds permitted a time analysis of each of these components. Records of right forearm movement of eight subjects were taken under the following three sets of conditions: I. No initial fatigue of either arm; this served as a control series. II. Left forearm fatigue from 60-second run with record of right immediately following. III. Initial fatigue of right forearm for 40 seconds before taking the record. In all series the subject was instructed to rotate the arm as rapidly as possible and to move each time the full distance between the restrictions. Actual record taking of the right arm movements required only about twenty seconds in a given series. In spite of this short time which developed very little feeling of fatigue as reported by the subject, he was rested for three minutes between series. Each subject participated twice under all three conditions.

Results and Discussion

Table I gives a summary of the data upon which are based the statistical results to follow:

TABLE I

No of subjects	8
No. of complete turns, Series I	445
No. of complete turns, Series II	414
No. of complete turns, Series III	341
Total kymographic readings (approx.)	37,000

Before presenting Table II it is necessary to refer to Fig. 6, page 38. The upper plateaus represent time required for reversing the direction of movement when the forearm is in the supination position. Pronation reversal is represented by the lower plateau. Downward movement is pronation progression; upward movement is supination progression.

[4] Unrestricted rotation with rapid movements and with forearm-upper angle approximately 100 degrees varies from about 120 degrees to 200 degrees.

TABLE II

COMPARISON OF SERIES I AND II. UNITS ARE IN TERMS OF 8.3 MILLISECONDS

Series I

No Initial Fatigue on Either Side

	PR	SP	SR	PP	Total
Mean	6.32	7.05	6.20	6.89	26.40
S.D.	2.77	1.23	2.40	1.41	4.68
$\sigma_{av.}$	0.127	0.058	0.113	0.065	0.22
V.	44.0	17.5	38.8	20.5	17.70
Number	473	449	452	473	445

Series II

Initial Contralateral Fatigue

	PR	SP	SR	PP	Total
Mean	7.35	6.65	7.55	6.49	27.96
S.D.	3.03	1.30	2.58	1.18	4.66
$\sigma_{av.}$	0.146	0.637	0.126	0.057	0.229
V.	41.3	19.5	34.2	18.3	16.7
Number	428	414	419	423	414
$M_2 - M_1$	1.03	−0.40	1.35	−0.40	1.56
C.R.	5.35	4.65	8.00	4.70	5.00

TABLE III

SERIES III

Initial Homolateral Fatigue

	PR	SP	SR	PP	Total
Average	12.78	9.77	10.79	9.82	42.26
S.D.	4.50	1.82	4.17	2.18	7.40
$\sigma_{av.}$	0.24	0.097	0.224	0.118	0.40
V.	35.00	18.60	38.70	22.40	17.50
Number	346	343	345	342	341

TABLE IV

PERCENTAGE OF INCREASE IN AVERAGES

	PR	SP	SR	PP	Total
I–II	16.3	−5.7	21.8	−5.8	5.9
I–III	100.5	38.6	74.0	42.7	60.0

In the table these components are referred to by initials in the following manner: PR—pronation reversal; SP—supination progression; SR—supination reversal; PP—pronation progression.

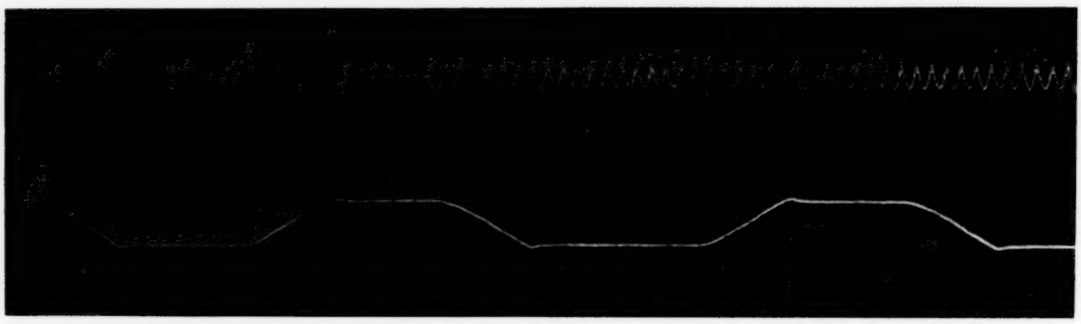

FIG. 6

1. *Crossed Effects of Fatigue.*

While the differences between the averages of Series I and II appear to be slight, the critical ratios indicate that those differences are reliably above chance. Crossed effects of a unilaterally developed fatigue are, therefore, evident. Examination of the category $M_2 - M_1$ in Table II shows that these differences between the averages are not all in the same direction. Time required for reversing the direction of movement has increased, while the time for the movement itself has decreased. These data furnish an answer to the tendencies noted in Part I. The slight reduction in the number of turns following contralateral fatigue is because of the longer time necessary to reverse the direction of rotation. The slight increase in amplitude is explained by (1) a more rapid movement, and (2) a delay in the initiation of reversal processes.

The data appear to indicate the operation of both facilitative and inhibitory processes. The movements, themselves, seem slightly increased while change of direction is slightly delayed. The condition of facilitation is more apparent than real. Both phenomena are probably due, rather, to a weak inhibitory process operating to delay at each rotation the initiation of antagonistic muscular contraction. Dodge and Bott (**8**) have shown that co-contraction of antagonistic

muscles is basic to rapid voluntary reciprocal movement. More specifically, they have shown that even before movement in a given direction has terminated active antagonistic muscle contractions are developing. To these observations it may be added that contractions of the antagonists prior to the moment at which they become dominant probably serve slightly to retard the movement in progress and to shorten the time required for reversing the direction of movement. If, then, a physiological condition is present which delays slightly the initiation of antagonistic contractions, the movement already in progress should be more rapid and the duration of the reversal components should be increased. The manner in which this slight inhibitory condition is transmitted to the opposite side is not known. The mechanism and the neural level of transmission are worthy of further investigation.

2. *Relative Variability.*

Direct comparison of the coefficients of variability for each of the components of movement indicates that the reversals are subject to the greater variability. This is true of all three series. Evidently, the centers of control are more readily influenced by fluctuating factors than mechanisms of peripheral response. The relation of movement variability (MV) to reversal variability (RV) is, approximately,

$$MV = \frac{RV}{2}.$$

How this equation would be modified by systematically changing the arc of forearm rotation is not known at present. In any case the problem is of importance in the further investigation of relationships between central control and peripheral response. The above equation appears to hold for all three series or sets of conditions. Contrary to the study of Manzer (**18**) fatigue has not increased variability. The conditions of the two experiments are not comparable, however. Manzer's study employed the ergograph with which records are primarily representative of unidirectional pulls against a load. The regulatory dynamics of such a

movement pattern may be quite different from those basic to rapid reciprocal movement. Boder (**2**) seemed to find that variability increased with fatigue for some of the components and decreased for others. Further studies of the relative variability of the components of reciprocal movement should reveal important aspects of the dynamics of the total reciprocal movement pattern.

Similar to the findings of Boder (**2**), the data of the foregoing tables show that the variability of the time required for a complete movement is usually less than the variability of the components. This is apparently the result of some sort of inter-compensation among the components whereby frequently short or long components are immediately followed by their opposites. In carrying out the instructed task the subject develops a pattern of movement the stability of which becomes dominant over the parts. Components may be extended or reduced in maintaining a relatively consistent rhythm of movement. Time required for the components of the total movement preclude a conscious regulation of each of the specific parts. The average time of these components varies from 50 m.s. to 65 m.s. This is comparable to time required for many reflex responses and is approximately one-half the time of practiced reaction time. In the dynamics of motor organization in which there is subordination of specific parts into a more stable whole, there is suggested a similarity to a perceptual organization wherein parts may be united to form a unitary whole. The structuring of the perceptual field with reference to the experiencing individual probably should have characteristics in common with the organization of motor response with reference to determining tendencies.

3. *Stability of Movement.*

In contrast to the variability of the reversal components is the relative stability not only of the total pattern but also of the progression components. The coefficients of variability for movement times range from 17.5 to 20.5 in Series I and II while the coefficients of variability for reversals range from

34.2 to 44.0. It appears that once the contraction or movement in a given direction is initiated it runs its course with almost mechanical regularity. In fact, the movement time is so regular and consistent that a difference of 3.2 m.s. between the averages of 58.5 m.s. and 55.3 m.s. becomes a reliable difference in approximately 400 cases.[5]

4. *Effects of Homolateral Fatigue.*

Evidence of the effects of fatigue upon centers of control is not confined to the results of Series II. Here, of course, the modification of movement subsequent to contralateral fatigue appears to indicate that neural centers have been affected. The data of Table IV also may be taken, with some reservations, as evidence that the fatigue developed by prolonged voluntary reciprocal movement is a condition found not only in the mechanisms of contraction but also in the mechanisms of control. It may even be suggested that the mechanisms of control are the more profoundly affected. If Series I and II are compared, the average duration of reversals may be noted as having increased while the average duration of progressions has decreased. A comparison of Series I and III shows that while all four components have increased, the reversal periods have been quite strikingly the more affected. If variations of the reversal period are due, principally, to changes in the dynamics of control centers, then Table IV furnishes evidence that these centers are more subject to effects of fatigue than the mechanisms of contraction. There are, however, peripheral factors which might conceivably produce changes in the reversal components, such as changes in permeability to the nerve impulse at the myo-neural junction, changes in viscosity of muscular tissue, and variations in chronaxie of the muscular response. Since it is not within the scope of the present paper to determine the significance of each of the four components of reciprocal movement, the interpretation of variations in the reversal period as representing principally variations in the control centers must be taken only tentatively. Were this point

[5] Figures from Table II, Column SP, are here translated to milliseconds by multiplying by .0083 second.

established, the general method of Part II should be of considerable value in further studies of reciprocal movement.

Summary and Conclusions

The present experiment has investigated the crossed effects upon voluntary movement of a unilaterally induced fatigue. The experimental procedures were separated into two parts. In Part I records were taken alternately of both right and left forearm rotations, *i.e.*, pronation-supination, under the two following sets of conditions: 1, No initial fatigue of either side; 2, Initial contralateral fatigue. Four subjects each contributed twenty experimental periods on as many successive days. The twenty periods for a given subject permitted ten instances for each forearm to operate under each of the two sets of conditions, that is, in ten trials the right arm movements preceded contralateral fatigue and in ten trials right arm movements were subsequent to contralateral fatigue. The same would hold for the left forearm. In all instances, the subjects were instructed to attempt their maximum in both rate and amplitude.

In Part II the apparatus was modified so that durations of each of the four components of reciprocal movement could be measured, *i.e.*, the durations of the two reversals and the two progressions. Records of right forearm rotations were then taken under the three following sets of conditions: 1, No initial fatigue, 2, Initial contralateral fatigue, and 3, Initial homolateral fatigue.

The results permit the following conclusions:

1. Contralateral fatigue appears to modify the homolateral movements by reducing rate and increasing amplitude of forearm rotation.

2. Contralateral fatigue modified the components of reciprocal movement by a light but significant decrease in progression time and by a slight but significant increase in reversal time.

3. Variability of reversal duration is more affected by both homolateral and contralateral fatigue than the progression duration.

4. Total movement, itself, is always less variable than the components of that movement.

(Manuscript received February 24, 1938)

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POSTURAL ACCOMPANIMENTS OF THE VOLUNTARY INHIBITION OF MICTURITION*

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While the human organism is constantly required to defer micturition, defecation, and consumatory acts related to other 'basic urges,' the postural reflections of this self-imposed inhibition have never been studied systematically. It is recognized, of course, that some individuals exhibit greater 'control' than others in their response to a basic tissue disturbance, but an adequate understanding of these differences is lacking. In fact, the whole subject of the inhibited urge has been shrouded in psychoanalytical vagaries so long that its physiological analysis has been seriously hampered. It is possible that such inhibition has neuro-muscular consequences which are related to problems of psychopathology; but as long as it is discussed in purely mentalistic terms, there is suggested an inability to quantify either the strength of the stimulating condition or the organism's response thereto.

It now seems that these difficulties are more apparent than real. When the excitation aroused by bladder tension is subjected to systematic control, the inhibition of the related consumatory act of micturition receives quantitative expression in postural and accessory mechanisms. The present report is concerned with the postural reflection of the course of inhibition under varying conditions.

The Experiments

Five adult males took part in the experiments. Prior to and during experimentation, each was placed upon a diet which allowed approximately 1,200 cc. of liquid daily. The subjects reported for observation one hour after the morning meal. At this time they micturated and drank 1,000 cc. of water. This was followed by rest on a cot during the recording of palmar skin resistance and electromyograms from the abdominal and perineal musculature. In order to avoid the influence of immediate

* Studies in muscular tension, series 2, no. 4.

physical exertion and 'reflex sweating,' no records were taken until fifteen minutes after water intake. The subjects were instructed to inhibit micturition as long as possible, with friendly competition an aiding incentive. After voiding the subject rested for a period of post-micturitional readings. Room temperature was held constant within two degrees.

The course of inhibition was studied for several days under each of the following three procedures: (1) subjects resting quietly through the entire period of voluntarily imposed inhibition, (2) subjects asleep, and (3) subjects engaged in activity between hourly readings. One record was taken in which changes in the actual bladder pressure during inhibition of micturition were recorded by inserting a catheter in the urethra and connecting it was an air-water manometer tube and a tambour writing on smoked paper.[1] In addition a control series was run wherein the subjects rested as in Procedure 1 but without water intake.

Palmar skin resistance and perineal and abdominal electromyograms were chosen for their ability to reflect postural change. There is now considerable reason to believe that fluctuations in resistance which accompany palmar sweating are accessory to the postural mechanisms and reflect general increments in muscular tension or reactivity.[2] It is also known [3] that the voluntary restraint of micturition is closely associated with contraction of the perineal musculature and to a lesser extent with abdominal contractions. Thus the inclusion of both electrodermal and electromyographic records was thought appropriate. The palmar resistance was obtained from large (1½″) non-polarizable (zinc-zinc sulphate) electrodes connected with a Wheatstone bridge resistance box with calibrated steps of 1,000 ohms.[4] The electromyograms were recorded photographically by means of a crystal oscilloscope connected with a four stage amplifier.[5] The electrodes were half inch gold plated discs taped to the skin previously rubbed with electrode jelly.

Procedure 1.—Postural accompaniments of inhibited micturition during rest.

It was recognized that muscular tension and reactivity might be influenced by physical exercise and mental exertion

[1] We used the technique described by Lewis, Langworthy and Dees (*Bull. J. Amer. Med. Assn.*, 1935, **105**, 2126–32), the only modification being that just enough water was introduced into the system externally to register changes in bladder pressure on the manometer tube.

[2] This relation, which was first suggested by the work of M. M. White (*J. Exp. Psychol.*, 1930, **13**, 267–277), has received definite confirmation by M. Wenger and I. Irwin (*Univ. of Iowa Stud.*, 1936, **12**, 143–178) and by G. L. Freeman and R. M. Simpson (*J. Gen. Psychol.*, **18**, 1938, 319). The probable neural connections making for such a relation have been discussed by C. W. Darrow (*Psychol. Bull.*, 1935, **32**, 720–721 and *Arch. Neurol. & Psychiat.*, 1937, **37**, 641–663).

[3] D. E. Denny-Brown and E. G. Robertson, On the physiology of micturition, *Brain*, 1933, **56**, 149.

[4] C. W. Darrow, Uniform current for continuous standard unit resistance records, *J. Gen. Psychol.*, 1932, **6**, 471–478.

[5] The Brush Corporation's oscilloscope type *S* was used. The amplifier circuit was a modification of that reported by R. C. Davis, The muscle tension reflex and two of its modifying conditions, *Indiana Univ. Pub.*, Science Series, 1935, no. 3.

more than by the inhibition of micturition. In order to bring out the effects of the latter factor in the records of postural change, our basic condition emphasized quiet rest following the standard intake of water. Systematic records were taken at five minute intervals to a time thirty minutes after micturition. As seen in the accompanying graphs, there is a marked tendency toward stepwise increment in the

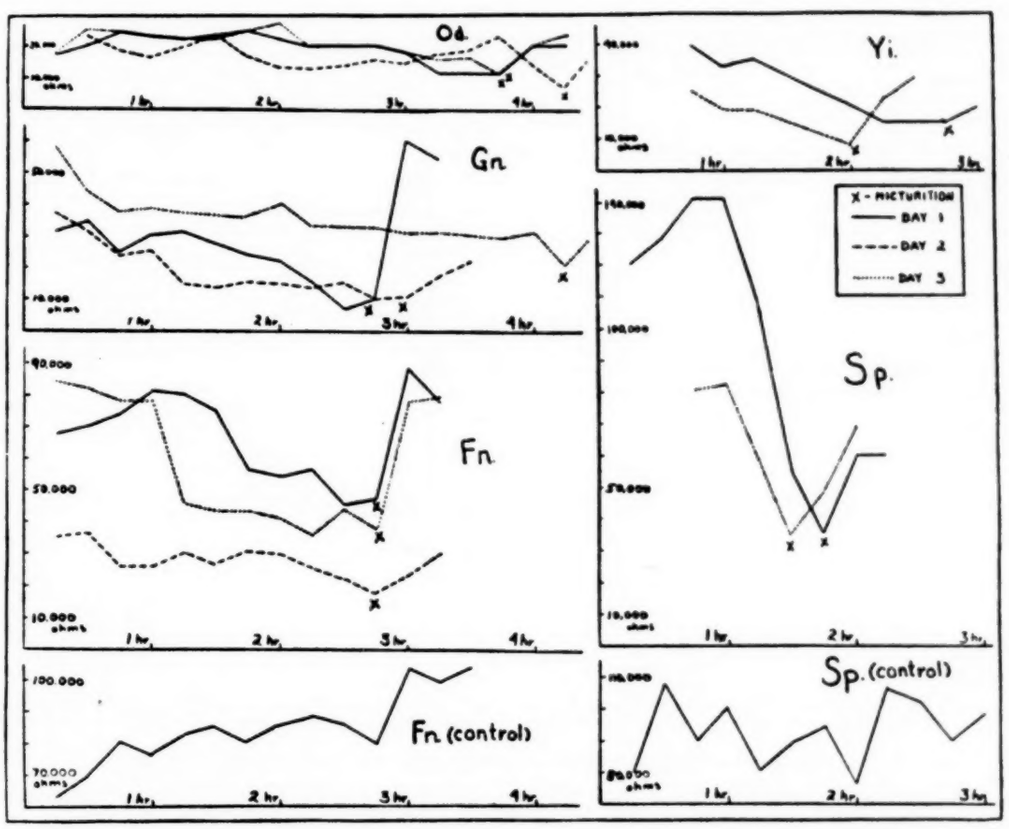

FIG. 1. Graphs showing changes in palmar skin resistance during inhibited micturition in the condition of quiet rest. The two graphs at the bottom of the figure are of the 'controls' run without 1,000 cc. water intake.

measures of postural activity until micturition is allowed to occur, after which there is exhibited a decrease in reactivity. This is not true of the control observations made in the absence of water intake. The fifteen minute averages of palmar skin resistance are plotted separately for each subject in Fig. 1 and their relation to the concomitant changes in action-current frequency is shown in Fig. 2.

Due to apparatus difficulties, the electromyographic curves were not complete for all subjects. In view of the fact that lowered skin resistance indicates increased bodily activity, the close reciprocal relation shown between the action current frequencies and resistance changes is very significant. While the myographic data reflect organic response to increasing bladder volume more rapidly and specifically than does palmar sweating, both are affected by the same condition.

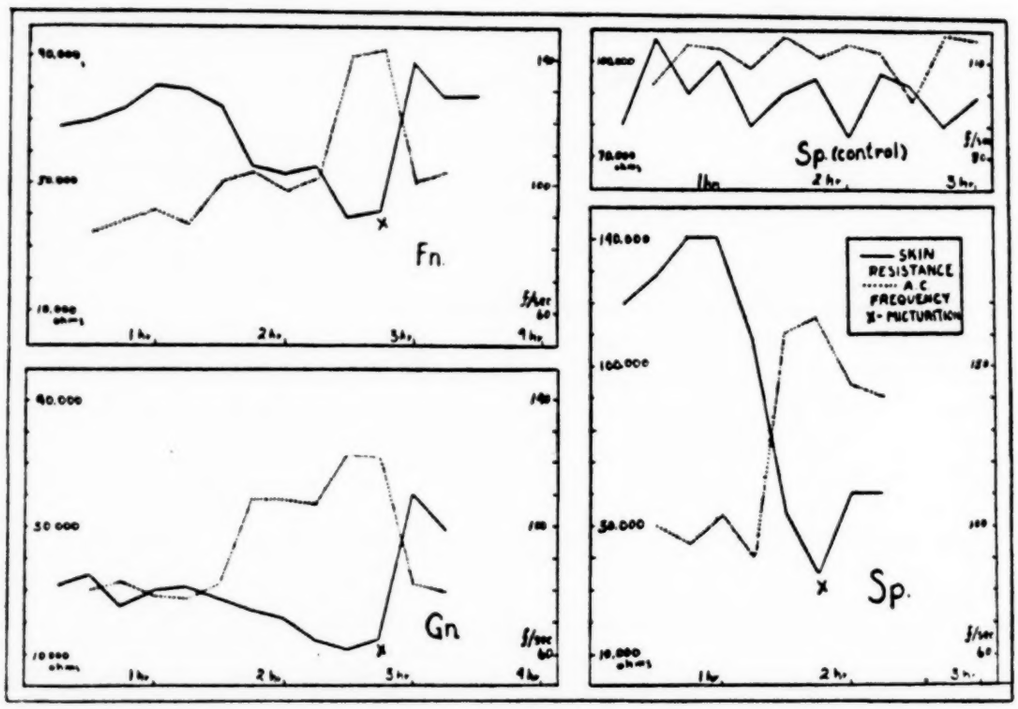

FIG. 2. Graphs showing concomitant changes in palmar skin resistance and action current frequencies from perineal and abdominal musculature during inhibited micturition in the condition of quiet rest.

The fact that subjective reports of the desire to micturate were frequently accompanied by increments in postural activity indicated that the actual state of the bladder should be studied in this connection. Since the effective stimulus for the micturatory impulse is known to be related to intravesical pressure and not to bladder tension and volume *per se*, one subject volunteered to repeat the procedure of inhibiting micturition with a catheter inserted into the urethra and vesical pressure read from an attached manometer. As this study was made in a hospital only the changes in palmar skin

resistance could be taken simultaneously with the bladder readings. The results, which are plotted in Fig. 3, show a marked relationship between decrements in skin resistance and rises in vesical pressure. Urine flows into the bladder until the vesical pressure is raised critically; then under the inhibitory control imposed there is a widespread postural readjustment probably involving relaxation of the bladder walls and increased contraction of accessory perineal muscles.

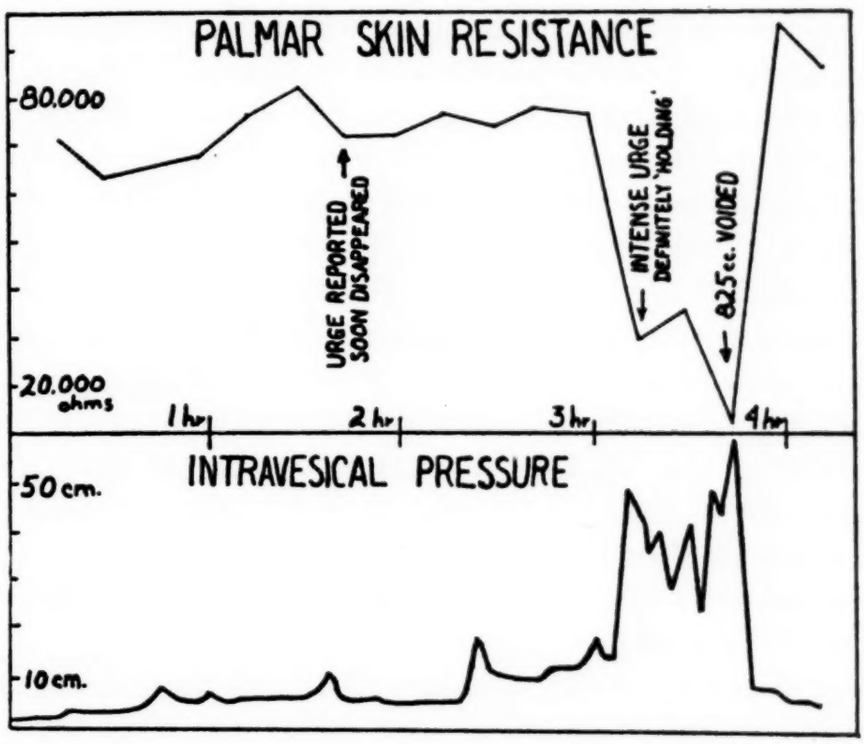

FIG. 3. Graphs showing the relation of changes in palmar skin resistance to changes in intravesical pressure during inhibited micturition in the condition of quiet rest.

Under such combined action the intravesical pressure falls, but the organism is now operating at a higher level of physiological activity than before. After a period of three hours the intravesical pressure has risen to an average height of 45 cm of water and the subject reports that he is 'definitely holding.' In another half hour urine is released involuntarily. Afterwards the intravesical pressure falls rapidly to its resting level and compensatory postural adjustments also decline. In our single experiment the desire to micturate apparently

correlated with critical rises in vesical pressure. But that such crises are not specific to the urge to micturate is indicated in the number of pressure changes which were reflected by increased postural activity but were not accompanied by a sensed desire. We are therefore inclined to agree with Denny-Brown and Robertson that "the sensation is only indirectly related to intravesical pressure and in such a way that increases in the area of the vesical wall, within limits of only very slight corresponding increase of passive internal pressure, markedly lower the threshold at which added spontaneous active contractions can produce the sensation. The reactionary contraction which is evoked by bladder distention is controlled by a restraining effort which at low volume is subconscious in operation—this process of adaptation or modification of reaction intrudes upon consciousness in greater degree as volume increases. Tightening of the perineal diaphragm during restraint induces small pressure increases of intra-abdominal pressure and correspondingly some fall in vesical pressure. Such restraint also has a direct effect on the state of the bladder so that spontaneous nervous discharges responsible for the reactionary contractions to distention are inhibited with ease." [6]

Procedure 2.—Postural accompaniments of inhibited micturition during sleep.

As a check upon the influence of the higher centers in the inhibition of micturition, changes in palmar skin resistance were recorded in three subjects during sleep. Following micturition these subjects drank 1,000 cc. of water and prepared for bed. Records were taken at 5 to 15 minute intervals from the time of retiring to a period 30 minutes after the subject awakened and micturated. Prior conditions

[6] The pioneer study by M. Mosso and P. Pellacini (*Arch. de Biol.*, 1882, 1, 97–291) indicated that the bladder could hold at even close intervals different volumes of water at the same intravesical pressure. It was also stated that the micturitional urge was stimulated whenever the pressure rose above 18 cc. of water. While subsequent work has confirmed the general position of Mosso and Pellacini, bladder adaptation has been found to be much greater at higher volumes of water than at low and is not in the nature of a readjustment to a constant level of intravesical pressure but a percentage readjustment to the tension induced by previous filling (*cf.* Denny-Brown and Robertson, *op. cit.*).

which might influence the resistance changes were kept as similar to those in Procedure 1 as was possible. While the observations were made at night instead of during the morning, previous work [7] indicates that time of day *per se* is not a factor in determining reactivity levels.

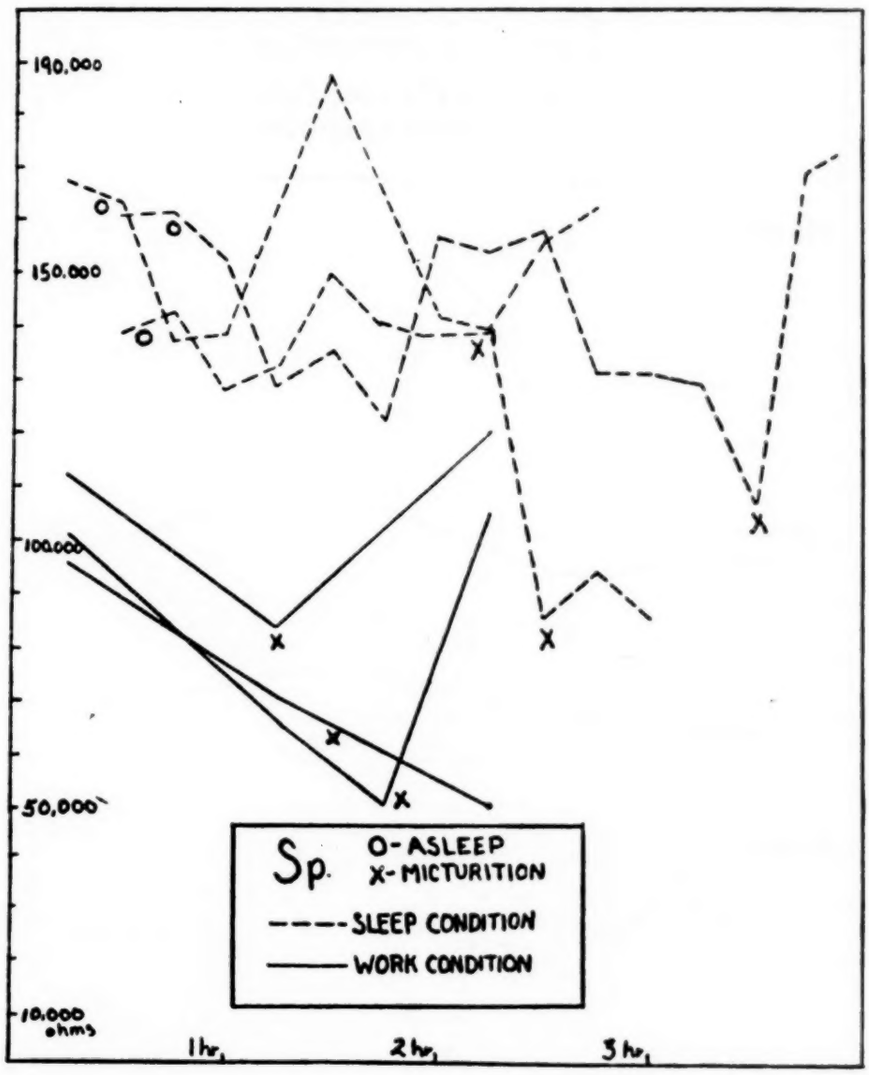

FIG. 4. Graph showing changes in palmar skin resistance for subject *Sp* during inhibited micturition in the sleep and work conditions.

As seen by the dotted lines in Figs. 4, 5, and 6, the changes of skin resistance assume somewhat different form according to the individual subject. The curves for subject *Sp* indicate two distinct periods of increased postural activity with

[7] G. L. Freeman, *Diurnal Variations in Performance and Energy Expenditure*, Chicago, Northwestern Univ. Press, 1935, pp. 27.

waking to micturate occurring at the peak of the second rise. Subject *Od* showed a tendency toward steady reduction in activity (as indicated by increased skin resistance) followed

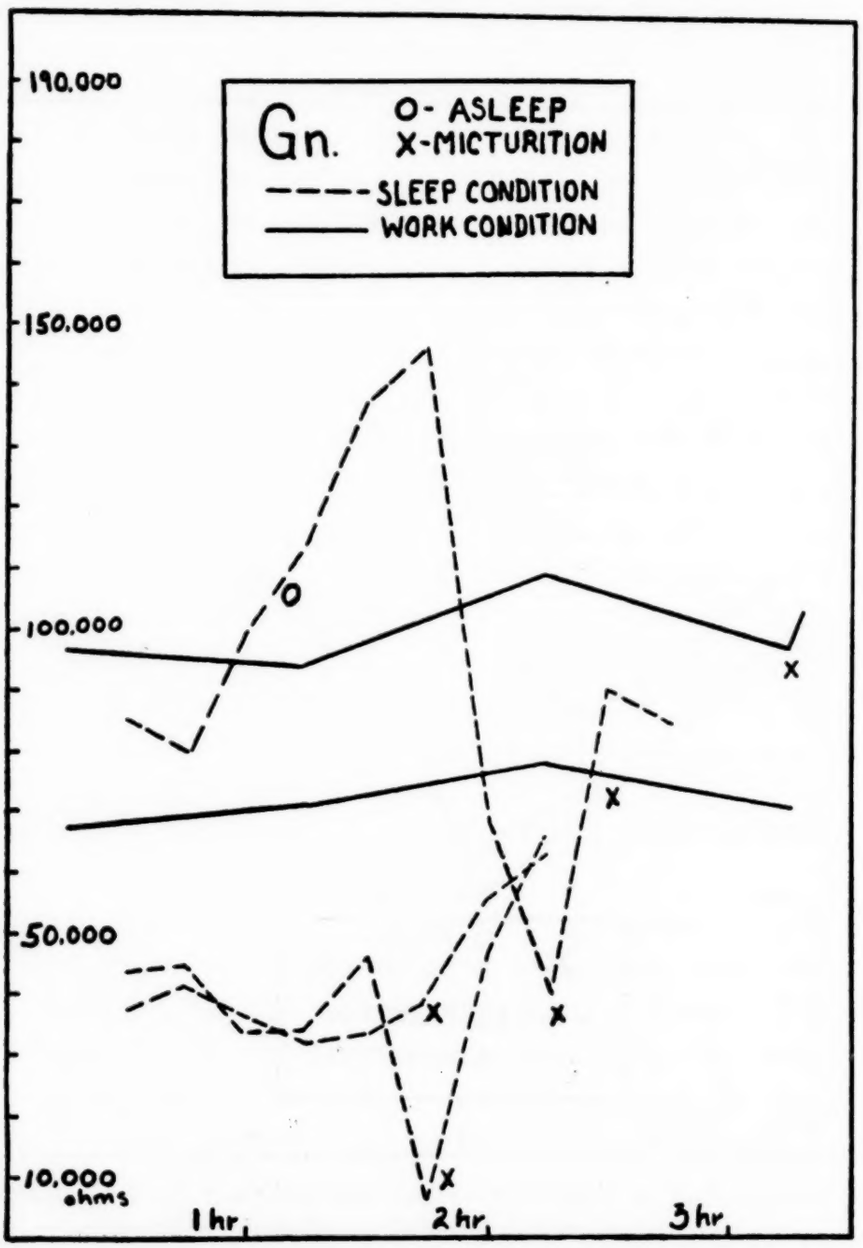

FIG. 5. Graph showing changes in palmar skin resistance for subject *Gn* during inhibited micturition in the sleep and work conditions.

by a more rapid rise. Awakening to micturate coincided with the period of decreased skin resistance and was followed by an increase in resistance as sleep was resumed. During two periods of observation subject *Gn* was unable to sleep

until after micturition, so that only the third period shows the extensive changes characteristic of subjects *Od* and *Sp*. The fact that the subjects invariably awakened during the

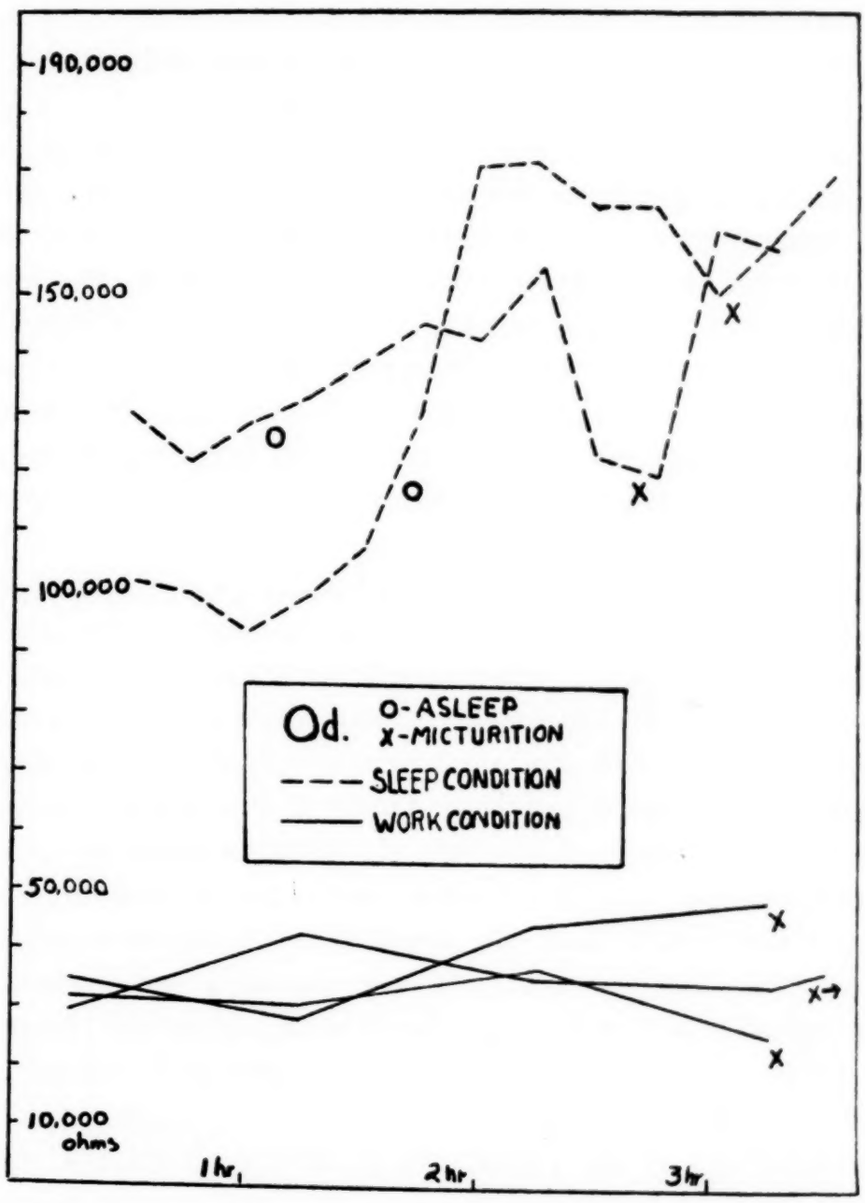

FIG. 6. Graph showing changes in palmar skin resistance for subject *Od* during inhibited micturition in the sleep and work conditions.

period of most rapid fall in skin resistance with desire to micturate seems to indicate that such changes reflect more or less specific postural adjustments to a critical increase in bladder tension. The fact that these premicturitional changes

in skin resistance are greater during sleep than in the state of waking rest, is due partially to the summation of the micturitional effect with changes incident to waking. Further comparisons and implications of these data are discussed in a later section.

Procedure 3.—Postural accompaniments of inhibited micturition during moderate physical activity.

As there is some reason to believe that physical and mental exertion affects micturition, it was thought desirable to compare the results obtained during sleep and rest with a condition requiring physical exercise in the period of voluntary inhibition. Following intake of 1,000 cc. of water, three subjects reported to the laboratory at half hour or hourly intervals until after micturition had occurred. Between the periods of observation the subject walked approximately one mile as checked by a pedometer and ended his trip by a slow climb up two flights of stairs.

As seen by the solid lines in Figs. 4, 5, and 6, it appears that the postural reflection of inhibited micturition is not as marked during work as during rest and sleep. In fact, with the exception of subject *Sp* the curves do not show the premicturitional fall and postmicturitional rise in skin resistance characteristic of both the rest and sleep conditions. This may be due to the relatively greater effect of physical exercise on the records of skin resistance acting to conceal changes concerned with the inhibition of micturition. It is also possible that such activity may actually have introduced biochemical and circulatory effects which relieved the organism from the necessity of making postural adjustments specific to the water intake.

Comparison of the Inhibition of Micturition under Conditions of Rest, Sleep, and Work.

Table I gives the period of inhibition and the amount micturated under conditions of quiet rest, sleep, and physical exercise. A comparison of the three subjects who took part in all experiments suggests that equivalent amounts of urine can be retained by the organism longer during quiet rest than during moderate physical exercise. Longer periods of in-

hibited micturition usually obtain for the rest condition than during sleep.

The fact that subject *Sp* inhibited micturition longer in sleep than during rest deserves special comment. Possibly some condition affecting the cortical inhibitory centers interfered during rest with the establishment of restraint. During sleep, in which inhibitory control is presumptively under the dominance of subcortical mechanisms,[8] the period of inhibition was much longer for this subject. Since there is evidence [9] that the subcortical mechanisms include centers which excite as well as inhibit tonic bladder contractions, the relatively low cortical inhibitory control in *Sp* might have been accompanied by some excitatory condition acting to maintain a hyperactive bladder tension. On the other hand the fact that the inhibition time of subjects *Od* and *Gn* was longer during quiet rest than sleep might be interpreted as the favorable balance maintained when lower inhibitory centers were sufficiently reinforced by the activity of the higher centers.

The results of this experiment indicate that the inhibition of micturition is affected by the degree and type of activity engaged in by the higher centers of inhibitory control. While it is well known that bilateral lesions in the motor cortex and internal capsule cause loss of voluntary control of micturition,[10] previous work on relative control in intact systems has been somewhat ambiguous. Mosso and Pellacini [11] consider that the functioning of the bladder is closely related to the intensity of psychological processes since marked changes in vesical pressure occur "when the subject exerts emotional or intellectual effort." Wiersma [12] states that both 'the diminution of consciousness' (sleep?) and 'intense

[8] P. M. Levin and O. R. Langworthy, Extra-pyramidal control of micturition, *Amer. J. Physiol.*, 1937, **118**, 483.

[9] J. Beattie and A. S. Kerr, The effect of diencephalic stimulation on urinary bladder tonus, *Brain*, 1936, **49**, 302–315.

[10] L. G. Lewis, O. R. Langworthy, and J. E. Dees, Bladder abnormalities due to injury of motor pathways in the nervous system, *J. Amer. Med. Assn.*, 1935, **105**, 2126–2132.

[11] M. Mosso and P. Pellacini (*op. cit.*).

[12] E. D. Wiersma, Psychical inhibition, *Proc. Konink. Akad. van Wetens. te Amstd.*, 1923, **26**, nos. 1, 2, 3.

concentration' cause increased inhibition of micturition, but his data are reported so loosely that their adequate interpretation is impossible. The figures given in his tables merely indicate that greater quantities of urine are excreted at some periods than at others, without recording the type of intervening activity. A questionnaire study by Ivy [13] suggests that the subject defecates more frequently instead of less frequently as the result of taking an examination. Hall [14] reports an increase in urination by rats in adjusting to new and unfamiliar situations.

Inspection of Table I shows that the period of inhibition and the amount micturated reflect our test conditions. Especially significant is the fact that much greater individual differences in micturition time are revealed in rest than in sleep. Subjects who are widely apart in the rest condition show approximately the same inhibition time with control shifted to the more automatic mechanisms which presumably operated in the sleep condition. The present experiment favors the view that while the cortical control centers are major factors in the inhibition of micturition, their relative quiescence during sleep does not permit the automatic expulsion of urine as soon as a critical vesical pressure is reached. Moderate physical exercise has the effect of diminishing the period of inhibited micturition, but whether this is due to circulatory and chemical effects resulting from the increased activity or to some 'drainage' of cortical inhibitorv impulses into other channels is not known.

Comparison of Postural Accompaniments of Inhibited Micturition during Rest, Sleep, and Work.

Table II suggests that postural reactions to inhibited micturition vary according to other conditions imposed. If the subject rests quietly following water intake, he is generally able to withstand an extensive series of vesical changes to gradually increasing volume. The general level of postural activity (as indicated by palmar resistance changes) is higher

[13] A. C. Ivy, unpublished communication with the writer.

[14] C. S. Hall, Drive and emotionality factors associated with adjustment in the rat, *J. Comp. Psychol.*, 1934, 17, 89–108.

than during sleep, but lower than during moderate physical work. In addition to these absolute changes in reactivity level, the table also indicates that marked changes in the variability of response occur under the different conditions. Greatest changes in palmar skin resistance occur during sleep.

TABLE I

SHOWING TIME OF INHIBITION AND AMOUNT VOIDED UNDER VARIOUS CONDITIONS

Subject	Rest (1)		Sleep (2)		Work (3)	
	Time	Amt.	Time	Amt.	Time	Amt.
Od	4 hrs. 15 min. 3 45 3 45	1300 cc. 777 750	3 hrs. 2 45 min.	1100 cc. 500	2 hrs. 15 min. 2 15 4 15	625 cc. 550 970
Average	3 hrs. 55 min.	942 cc.	2 hrs. 52 min.	800 cc.	2 hrs. 55 min.	715 cc.
Gn	4 hrs. 15 min. 3 15 3	1300 cc. 1250 800	Awake Awake 2 hrs. 45 min.	 825 cc.	3 hrs. 15 min. 2 45	750 cc. 875
Average	3 hrs. 30 min.	1117 cc.	2 hrs. 45 min.	825 cc.	3 hrs.	812 cc.
Sp	1 hr. 45 min. 1 30	750 cc. 400	3 hrs. 30 min. 2 15 2 30	735 cc. 650 600	1 hr. 45 min. 1 15 1 30	800 cc. 470 600
Average	1 hr. 38 min.	625 cc.	2 hrs. 46 min.	662 cc.	1 hr. 30 min.	625 cc.
Ave. of average	2 hrs. 58 min.	925 cc.	2 hrs. 47 min.	762 cc.	2 hrs. 28 min.	717 cc.
Yi	2 hrs. 2 hrs. 15 min.	535 cc. 650	These subjects did not participate in Procedures 2 and 3.			
Average	2 hrs. 8 min.	593 cc.				
Fn	2 hrs. 45 min. 2 45 2 30	840 cc. 850 790				
Average	2 hrs. 38 min.	827 cc.				

Subjects who inhibited micturition the longest show the least fluctuations in palmar resistance. From the table it might be inferred that variability is a function of the absolute reactivity level at which the subject is working. This point of view has support in the work of Wenger and Irwin,[15] who found a correlation of + .9 between absolute resistance level

[15] M. Wenger and O. Irwin (*op. cit.*).

and amount of variation (Z scores). However, individual aberrations are suggested by the fact that our subject (*Od*), who was least variable and who inhibited micturition longest under conditions of quiet rest, had the highest recorded reactivity level instead of the lowest.

TABLE II

SHOWING PALMAR (THOUSAND OHM) RESISTANCE LEVELS DURING INHIBITED MICTURITION UNDER CONDITIONS OF REST, SLEEP AND WORK

Subject	Rest		Sleep		Work	
	Daily Ave. P.R.L.	A.D.	Daily Ave. P.R.L.	A.D.	Daily Ave. P.R.L.	A.D.*
Od	19 23 20	4 5 5	132 139	12 29	35 39 34	
Gn	46 29 21	14 11 5	40† 54† 94	12 23 32	59 100	
Sp	62 93	15 34	150 103 135	17 10 12	105 122 72	
Yi	25 18	7 8				
Fn	67 28 59	12 4 18				

* A.D.'s not computed were due to limited cases.

† No sleep during these observations.

DISCUSSION

Though it is evident that the voluntary inhibition of micturition finds reflection both in general and local postural adjustments, the correct interpretation of our data is not entirely clear. From reports made during the progress of the experiment, it is apparent that many of the stepwise increments in postural activity accompanied the desire to micturate. It is not known whether these changes represent increased irritability and restlessness or are a neuromuscular reinforcement acting to offset the micturitory impulses. Both factors are probably involved in the records. The

correlation between changes in palmar resistance and intravesical pressure favors the view that in the rest condition we are actually measuring compensatory adjustments to an inhibited urge.

Work by other researchers indicates that the restraint of micturition during waking is intimately connected with inhibitory cortical and subcortical control. According to Denny-Brown and Robertson [16] the human bladder reacts to distention by reflex contraction of its wall which, when intensive and extensive enough, will expel the fluid contents. This reactionary contraction to distention is controlled by inhibitory volleys of cerebral origin. The volleys act directly on the outgoing spinal motor neurones whose discharge causes the expulsive contraction and the bladder muscle, losing some of its tone, enlarges to cause a fall in vesical pressure. Indirectly the volleys lower the intravesical pressure by contracting the perineal diaphragm and so raising the passive intraabdominal pressure. The voluntary act of micturition is inseparably associated with relaxation of the musculature of the perineum. Thus normal micturition time is entirely secondary to reflex contractions of the bladder and can be regarded as being determined solely by variations in cortical and subcortical inhibition of the mechanism of spontaneous reaction to distention. Lewis, Langworthy and Dees [17] have pointed out that "the frequency of micturition is largely a physiological abnormality and is not dependent on fundamental anatomic changes making the bladder small." On the side of control mechanisms, they have shown that bilateral lesions of the cerebral cortex and corpus striatum result in frequent and precipitous emptying of the bladder. No voluntary control can be established, though if the sensory fibers are intact the patient may be aware of the imminence of micturition. Langworthy and Kolb [18] have shown that removal of motor cortices in animals causes an immediate decrease in vesical capacity. In a later study

[16] D. E. Denny-Brown and E. G. Robertson (*op. cit.*).

[17] L. G. Lewis, O. R. Langworthy and J. G. Dees (*op. cit.*).

[18] O. R. Langworthy and L. C. Kolb, The encephalic control of tone in the musculature of the urinary bladder, *Brain*, 933, **56**, 371.

they [19] demonstrated the cortical control of micturition by electrical stimulation. The extra-pyramidal system carries the subcortical control centers and has been extensively investigated by Barrington,[20] by McGoun, Kabat and Ranson,[21] by Beattie and Kerr,[22] and by Levin and Langworthy.[23] The exact relation of cortical and subcortical mechanisms in the inhibition of micturition is not yet clear, two interpretations being possible; in one the cortical mechanism may be thought to take over the inhibition of micturition from subcortical mechanisms as the bladder distention increases in degree; in the other the cortical mechanism may be thought of as constantly assisting the subcortical mechanisms. In view of the discovery of diencephalic centers for increasing and decreasing the bladder tonus, it is possible that the cortical control normally acts to reinforce the action of the subcortical inhibitory mechanisms and to inhibit the action of the subcortical excitatory mechanisms. That in some instances the cortical factor might favor a predominance of subcortical excitatory volleys is indicated by cases in which restraint of micturition is less in waking than in sleep. Kempf [24] has pointed out that excessively repeated acts of micturition in psychoneurotics indicates the presence of a rather fixed bladder tonus in the absence of appropriate cortical control.

In view of available knowledge concerning cortical and subcortical control of micturition, we are inclined to believe that the inhibition time for quiet rest provides a measure of *inhibitory cortical control.* We have already mentioned that inhibition time is not fundamentally a matter of differences in bladder size. But more specific point is given to the

[19] O. R. Langworthy and L. C. Kolb, Demonstration of encephalic control of micturition by electrical stimulation, *Johns Hopkins Hosp.*, 1935, **36**, 37.

[20] F. J. Barrington, *Quart. J. Exp. Physiol.*, 1925, **55**, 81.

[21] H. V. McGoun, H. Kabat, and S. W. Ranson, *J. Compar. Neurol.*, 1936, **63**, 211.

[22] J. Beattie and A. S. Kerr (*op. cit.*).

[23] O. R. Langworthy and P. M. Levin, Extra-pyramidal control of micturition: The effects of lesions in the segmentum of the midbrain, *Amer. J. Physiol.*, 1937, **118**, 483.

[24] E. J. Kempf, The autonomic functions and the personality, *Nerv. and Ment. Dis. Monog.*, 1921.

argument in our finding that individual differences in waking micturition time disappear in the sleep condition (when the more automatic subcortical mechanisms are largely released from cortical control).

Our work has shown that voluntary inhibition of micturition involves a readjustment of the total organism. 'Energy' has been mobilized, and this is apparently expressed in diffuse general increments in bodily activity and in specific tensions in the perineal and abdominal musculature. As a result of such readjustment vesical pressure drops appreciably and the 'holding' postures may be slightly relaxed. Obviously there is a limit to the postural compensation for increasing bladder content. Of the two factors which are mainly concerned in setting this limit, the potential extent to which the bladder can relax has the least functional significance. More important is the degree of inhibitory control which the higher centers can supply over the spontaneous expulsive contractions. It will be recalled that, independent of micturition time, the change in reactivity level is greatest immediately preceding micturition. If one assumed that voluntary control of micturition depended upon a particular excitation-inhibition ratio, heightened compensatory adjustment might indicate when the optimal point has been reached. We are not sure how much longer voluntary inhibition could actually have been continued in the present experiment. Future work should push the subjects to an end-point where there is automatic discharge of vesical contents. Herein we might expect to find great individual differences. That these differences might be related to inhibitory control in other 'emotional' and conflict situations is a possibility that is now being explored.

(Manuscript received February 14, 1938)

THE EFFECT OF DIFFERENT TYPES OF STIMULATION UPON THE pH OF HUMAN PAROTID SECRETION

BY A. L. WINSOR AND BARNEY KORCHIN

Cornell University

For more than a century investigations of the qualitative variations of salivary secretions have been reported. Although as early as 1835 Donné (**6**) reported upon the alkalinity and acidity of saliva in health and disease respectively, it was not until the work of Foa (**7**) and Kirk (**17**) that studies were made on the actual hydrogen ion concentration of the secretions. An exhaustive examination of the widely scattered literature reveals the fact that studies have since been reported in a score of scientific journals representing many fields of research. These investigations taken as a group are significant chiefly for their contradictions and confusion. If one examines the experimental techniques employed in these studies, it is no longer surprising to find the literature so replete with incongruous data.

Obviously, errors and difficulties in collection, as well as inadequate methods of pH determinations, account to a large degree for these inconsistencies. In general, mixed salivary secretions have been used. When collecting such secretions it is almost impossible to obtain samples which do not come into contact with organisms (caries, etc.) and other factors within the oral cavity which may alter their chemical consistency. In many studies the secretagogic agents themselves were permitted to contact the secretions.

The possible sources of error can be divided into (1) those due to methods of collection and (2) those due to techniques of pH determination. As for the latter, errors associated with delayed determinations, dilutions of samples, centrifuging, and inadequate apparatus (colorimetric methods, untreated glassware, etc.) have been most common. Since the errors

associated with these techniques have already been discussed by other investigators (**3**, **9**, **31**) further discussion is unnecessary here.

It is probably from the differences of the methods of collection of the salivary secretions that the more important contradictions in the literature have arisen. Although a study of the pH of the mixed secretions may offer an analysis of the secretions as they exist after contact with other factors within the oral cavity, the contamination with other substances will inevitably becloud any basic principles of the glandular secretion. For a true analysis of the secretions as they emanate directly from the glands it is imperative to collect the secretions from each gland separately before mixture with the other secretions or foreign substances. The modified Lashley suction disc that we employed in our study is the only apparatus which permits, for quantitative and qualitative analysis, the painless collection of secretion from a single salivary gland of a normal healthy human being.

In the past, several studies have been made on single glands. But the use of fistulæ or cannulation obviously precludes the possibility of obtaining a normal comfortable subject from whom a normal inactivated secretion could be obtained. Thus, for example, in the investigation of Clark and Carter (**5**) they cannulated the parotid gland and obtained a secretion with a pH of 6.40. But they could not obtain a normally flowing secretion and had to activate the gland in order to secure a large enough sample for the pH determination. We will show later in this paper that the parotid secretion obtained without extero-stimulation has a different pH value from that secured under the conditions described in Clark and Carter's work. They compared the pH value of 6.52 of the mixed saliva obtained from the same individual with his parotid secretion of pH 6.40. Naturally, they conclude that the difference is slight. But such is not truly the case. In our studies the average difference between the normal inactivated parotid and mixed secretions is about .9 of a pH unit. The difference in the two results lies chiefly in the fact that the parotid secretion collected by Clark and

Carter was an activated secretion whereas the mixed saliva was obtained without extero-stimulation.

Another important source of experimental error has been the failure to consider the distribution of stimulation or activity of the glands immediately preceding the collection of the secretions. One of us (Winsor (**35**)) had shown in an earlier paper the necessity of considering the activation of the gland prior to collection. We have found that the secretion which accumulates in the alveoli of the glands after excessive activation is more alkaline than that which is secreted after long periods of rest or salivary inhibition. The secretion which is first eliminated includes that which had accumulated in the glands prior to the stimulation. This fact has often been neglected and will always be a possible source of experimental error in the investigations of all glandular reaction.

In some of our preliminary studies we have observed that the parotid secretions seem to be less under voluntary control than the submaxillary and sublingual secretions. Because of this fact, contamination with other factors, exposal to air, and the difficulty of obtaining relatively comparable mixtures of the salivary secretions, the studies which employ the technique of expectoration will always be invalid for exact experimental work.

Method

Since the technique employed for the collection and measurement of the parotid secretion has already been described at length in an earlier report (**34**), a detailed consideration will not be necessary here. Suffice it to say that for the collection of the secretion a small disc was fastened by suction over the mouth of Stenson's duct. From the inner chamber of the disc a small air-tight drainage tube passed through the corner of the mouth carrying the secretion to small calibrated vials. The secretion was collected under toluene and pipetted out when the pH determinations were made. When even more precise quantitative analyses were necessary, the secretion as it accumulated in the vials would displace an equal volume of air which pushed a small column of water through a calibrated tube capable of measuring it in hundredths of a cc.

The collecting device itself does not affect the flow of secretion or seriously interfere with the mouth movements of the individual. The apparatus is simple, painless, and capable of accurately measuring variations in reaction. In most experiments the secretions were collected from both parotids simultaneously. The subjects quickly become adapted to the presence of the discs and after a few minutes are quite comfortable. Even with discs on both parotids the subjects are able to converse and eat and drink in a normal fashion.

The mouth of each subject and all apparatus used was carefully cleaned and rinsed with distilled water before and after each part of the experiment. Since oxidation and loss of CO_2 have been observed by other investigators to affect the pH of the secretion collected, our experiments were so controlled that the secretion was exposed to air only at the time of the pH determination. Although Michaelis and Pechstein (**23**) and Starr (**31**) showed that dilution of saliva has but little effect on pH, we tried to obviate even such small errors and used only undiluted samples. The suction discs used are so firmly attached to the mouth of the ducts that the secretion collected did not come into contact with any foreign substance. The secretion collected is the secretion as it leaves the papilla of the duct, but remains uncontaminated by the secretagogic agents or other factors within the oral cavity.

The hydrogen ion concentration was determined electrometrically with the Beckman glass electrode pH meter. The electrical system of this pH meter is said to be accurate within 0.01 pH unit. The apparatus was tested with a standard acetate buffer solution and found to be in perfect condition before and after each set of determinations.

The subjects were seated in front of a small table and instructed to assume a comfortable posture. For records of a control, that is, normal secretion, the subjects were instructed to avoid excitatory movements of the tongue or throat, except as directed, and to keep their mouths closed. In order that accumulated secretions from other salivary glands might not interfere with the throat movements, the subjects were permitted to swallow at the end of every five minute period when the control secretions were obtained.

The proprioceptive stimuli used were chewing tasteless boluses of gum and rubber tubing, or the pure masticatory process without other activating agents. When proprioception was used the rate of chewing was kept constant by chewing at definite intervals to the beat of a metronome. To obtain olfactory stimulation we constructed a special device that provided a constant olfactory stimulation by circulating fluids past the nasal cavities. The gustatory stimuli were standard solutions of the primary taste qualities. To obtain unilateral gustatory stimulation we constructed a modification of the Hahn-Günther (**12**) stimulator. We were thus able to stimulate a portion of the tongue without diffusion of the secretogogic agent over other areas. For summated stimulation we used a wide variety of standard food products. The secretions were secured in a wide variety of experimental situations including periods of different types of mental activity and emotional and fatigue states.

Care was taken to consider the nature of the activation of the glands prior to the experiment. Thus in all crucial experiments the secretions were collected from 1½ to 2 hours after a meal. The time to collect 1 cc. of the secretion was in all cases carefully measured.

Hundreds of pH determinations were made of the secretions of High School and College students. Male and female subjects were used, with an age range between 13 and 23 years.

Results

The first series of experiments was designed to measure the pH of parotid secretion flowing at different rates and activated by a variety of stimuli. Collections were made when the subject was seated quietly at the desk to obtain the normal

flow, and when different secretagogic agents were used to produce more rapid rates. Gustatory, proprioceptive, ol-

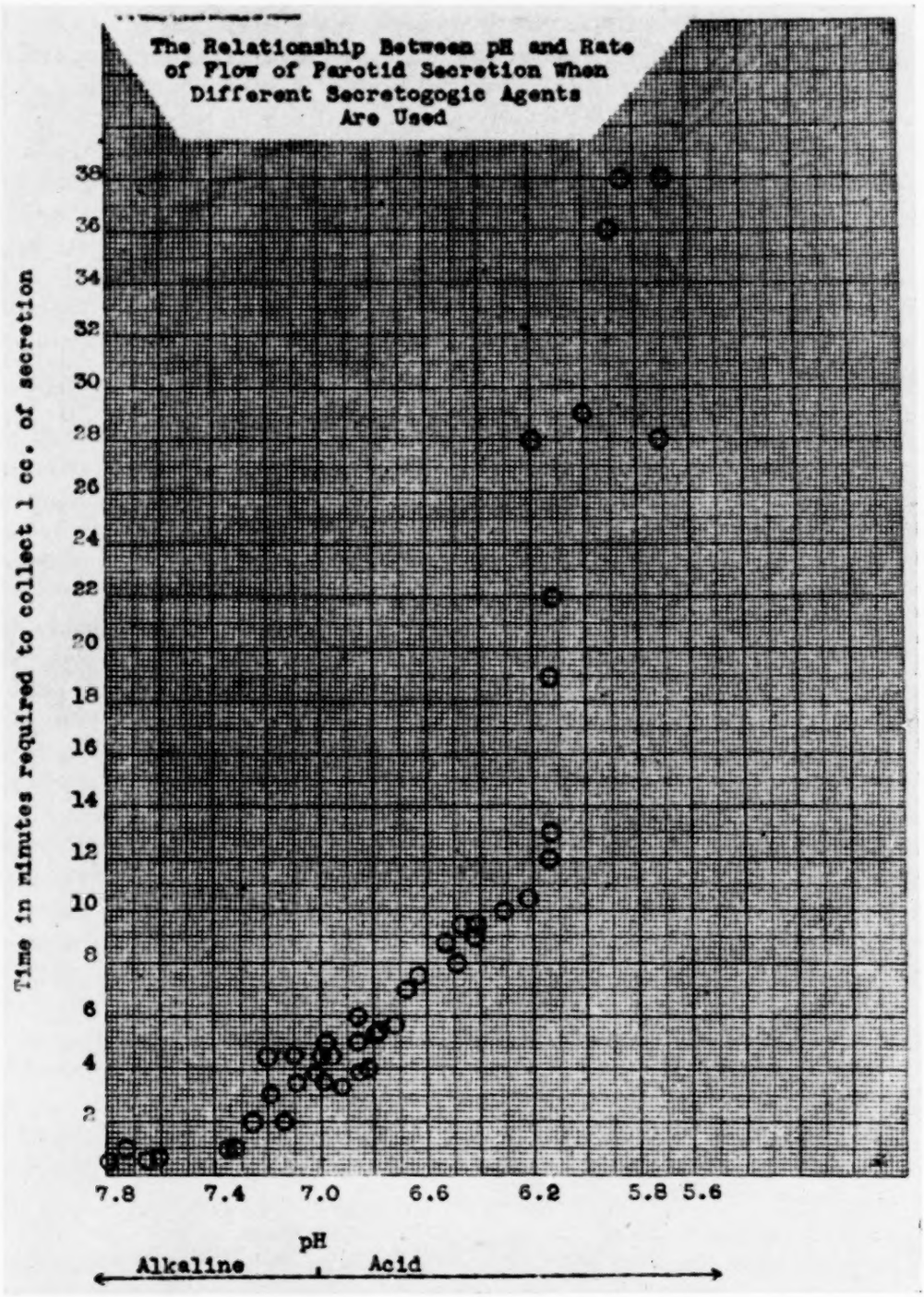

FIG. 1

factory, and summated stimuli were used, and the rate and pH in each case determined. Figure 1 represents the relationship of the rate and pH recorded under these conditions.

The ordinates represent the amount of time taken to collect 1 cc. of parotid secretion from one gland when different types of stimulation were used. It will be observed that in this experiment it sometimes took 38 minutes to collect the standard amount and that under different conditions 1 cc. was collected in a fraction of a minute. The abscissas represent the pH readings beginning with an alkaline reading of 7.8 and extending to an acid reading of 5.6. The ranges in pH for this subject in these experiments are from a pH of 7.8 when the flow proceeded at the rate of 1 cc. in less than a minute to a pH of 5.7 when 1 cc. was collected in approximately 38 minutes.

A glance at the figure shows that the more rapidly flowing secretion was more alkaline while the slower rates are paralleled with a much more acidic secretion. Obviously, in spite of the nature of the secretagogic agent there seems to be in these data a high positive relationship between the pH and rate of flow of the parotid secretion. It will be noticed that at times the pH does not quite go hand in hand with the rate of secretion. But it is almost impossible to keep the rate constant during the time of collecting a sample of secretion, and to this the slight divergences from the curve may in part be attributed.

In order to check this phenomenon further a second series of experiments were planned. With the suction discs on both the right and left ducts the subjects were given a piece of rubber tubing to chew first between the right and then between the left molar teeth. It has already been shown in earlier reports (**19**, **36**) that the rate is much more rapid on the side of the greater proprioceptive stimulation than on that of the opposite side. The pH of the secretion from both glands with this type of activation is shown in Table 1. When the rubber was chewed for 10 minutes between the right molars $\frac{1}{2}$ cc. was collected from the left gland and $1\frac{3}{4}$ cc. from the right gland. The pH of the secretion from the left gland was 6.03 and from the right 7.11. The rubber was then chewed on the left side for 10 minutes, yielding $1\frac{1}{4}$ cc. from the left gland with a pH of 6.72, and $\frac{1}{2}$ cc. from the right with a pH of 6.15. (This person was later discovered to be right

glanded; that is, he normally secretes more from the right than from the left parotid. We will report our further investigations of this problem of glandedness and lateral dominance in a subsequent paper.)

TABLE 1

THE EFFECT OF A UNILATERAL STIMULATION UPON THE RATE OF FLOW AND pH OF THE SECRETION FROM BOTH PAROTID GLANDS

Activation	Time	Left Parotid		Right Parotid	
		Amount Collected	pH	Amount Collected	pH
Chewed piece of rubber tubing once per second between right molars	10 min.	½ cc.	6.03	1¾ cc.	7.11
Chewed piece of rubber tubing once per second between left molars	10 min.	1¼ cc.	6.72	½ cc.	6.15

In these experiments the relationship of rate and pH holds even when the secretion is collected from the two glands simultaneously and the glands are activated with different intensities of stimulation. We have performed numerous experiments of unilateral stimulation in which an acid secretion would be obtained from the right parotid while at the same time an alkaline secretion flowed from the left gland, and vice versa.

TABLE 2

VARIATIONS OF pH AND RATE OF FLOW OF PAROTID SECRETION WHILE CHEWING DIFFERENT SIZED BOLUSES OF FLAVORED GUM

Nature of Stimulation	Amount Collected	Time	pH
Normal flow (inactivated)	1 cc.	40 min.	5.53
Mastication process	1 cc.	19 min.	6.11
Chewing ¼ stick of gum	1 cc.	2½ min.	7.28
Chewing ½ stick of gum	1 cc.	1 min.	7.46
Chewing 1 stick of gum	1 cc.	¾ min.	7.59
Chewing 2 sticks of gum	1 cc.	½ min.	7.62

In a third experiment (see Table 2) which illustrates clearly the principle here delineated different sized boluses of flavored

gum were used to activate the glands. The time recorded to collect 1 cc. of secretion and the pH determinations were made for the normal flow, the mastication process and chewing $\frac{1}{4}$, $\frac{1}{2}$, 1, and 2 sticks of gum. It took 40 minutes to collect 1 cc. of secretion at the normal rate of flow and the pH for this sample was 5.53. When 2 sticks of gum were chewed 1 cc. was collected in $\frac{1}{2}$ minute with a pH of 7.62. The intermittent rates of flow and pH values are closely paralleled.

It is of interest to note here that with the more powerful secretagogic agents we found it possible to change the normally acidic parotid secretion into an alkaline one in less than one minute. The change in some cases was more than 2 pH units.

In an effort to investigate individual differences in pH curves a number of subjects were used and their secretions collected when flowing at various rates. The results from five of these subjects appear in Fig. 2. The various rates shown for each individual resulted from a variety of activating agents used in a given experimental period. The same relationship between rate and pH which appeared in previous experiments is apparent here. The rather wide differences in pH for different individuals suggests the need for some correlation studies with factors such as temperament, health, dietary habits, and the like.

We then performed a series of experiments to check for the parotid secretions the hypotheses of Popow and Kudrjawzew (**27**) and that of Starr (**32**) as to the factors involved in hydrogen ion changes of mixed salivary secretions. The former two investigators assert that the hydrogen ion concentration is inversely proportional to the hydrogen ion of the fluid placed in the mouth to stimulate its secretion. Starr maintains a relationship between alveolar CO_2 and salivary pH; an increase in the former being associated with an increase in the latter.

The results obtained by Popow and Kudrjawzew were probably due to the fact that the substances of high hydrogen ion concentration which they used in their experiments were more powerful secretagogic agents than the substances of

lower hydrogen ion concentration, and therefore collected more alkaline secretions with the more acidic activators. Although generally it is true that the more acidic substances

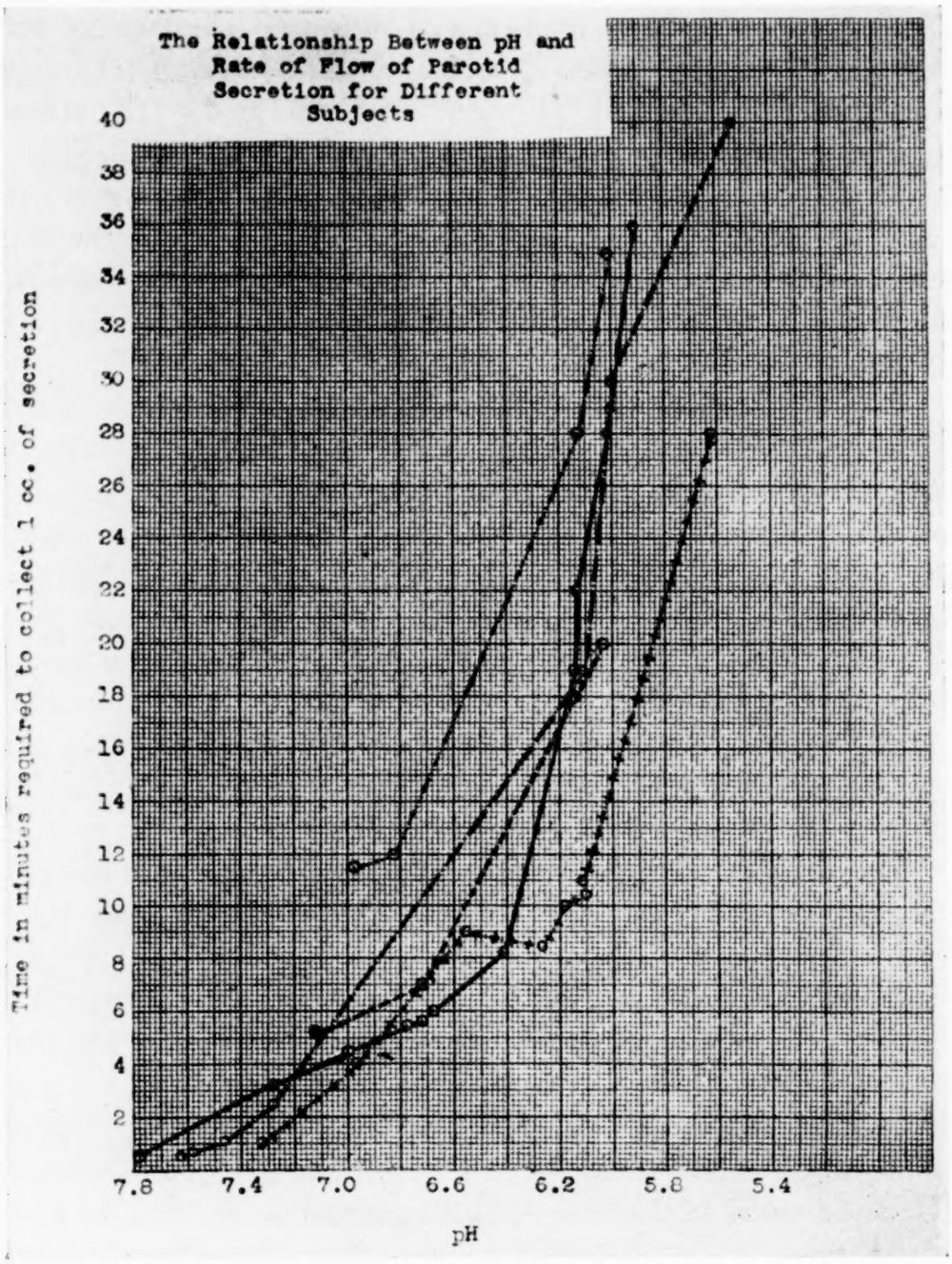

FIG. 2

will elicit a more alkaline secretion, our experiments using summated and proprioceptive stimulation had clearly demonstrated the necessity of considering the rate of flow of the

secretion. If the rate of flow were kept relatively constant, we were able to obtain parotid secretions with a pH of about 7.6 by activation with acidic acid, bread, flavored gum, and various fruits. We were also able to secure samples of secretion with a pH of 6.6 by activation with certain salt, sugar, alkaline and even dilute acid solutions, as well as by chewing pieces of rubber tubing. It was obvious after such experiments that factors other than the pH of the secretagogic agent are to be considered. In the data we obtained, the parallel between the rate of flow and pH of parotid secretion held despite variations in pH of the activating agents.

We were not able to find any consistent relationship between parotid pH and pulmonary ventilation. At times the pH would decrease and at times increase after the performance of the experiments described by Starr. The decrease or increase in almost all cases was associated with differences in the rate of flow. For some individuals the deep breathing exercises were invigorating and the resultant feeling of well-being was coupled with an increased salivary flow and therefore a slightly more alkaline secretion.

In our preliminary experiments with fatigue and emotional states upon parotid pH we have duplicated for that secretion some of Starr's (**30**) findings upon the mixed secretions. That is, when the individual was fatigued or deficient in the energy at his disposal the salivary pH was more acidic than when the individual was more energetic. But we observed that in such cases again the pH and rate of flow were paralleled. Thus, in very fatigued states the secretion flowed very slowly, whereas in the more energetic states the secretion was more abundant and more alkaline.

The average pH of the normal inactivated parotid secretions observed was 5.83 (with individual variations from 5.52 to 6.13). This value is much lower than was usually thought to be the case. But it is well to remember that in the earlier studies the secretion obtained was usually activated in some way and consequently a more alkaline secretion was obtained.

We noted pH values of inactivated secretion as low as 5.43 and when activated as high as 8.18. But the normal indi-

vidual range that was obtained in our experiments was about 2 pH units. The diurnal variations of parotid pH seem to parallel the variations with the rate of flow and previous activity of the glands. Thus, just prior to a meal when the appetite is good, that is, a more abundant anticipatory flow of the secretions, a higher pH was noted. During a meal the secretion is definitely alkaline. The post-prandial increased parotid flow that was noted in an earlier study has a slightly higher pH than that secreted in the mid-afternoon.

Discussion

Though no systematic and careful investigation of the effect of a wide variety of secretagogic agents and experimental situations upon the pH of parotid or mixed secretions has been made in the past, many interesting, but isolated facts have been observed. Thus, for example, we learn from Starr (**30**), Rich (**29**), Wittkower (**38**), Wittkower and Pilz (**39**), Ludlum (**20**), and others, that emotional states may alter salivary acidity. Starr, Rich, and Ludlum have found that the excited states usually were associated with a less acidic secretion. Grossman and Brickman (**11**) reported that the pH range of nocturnal saliva, *i.e.*, during sleep, is lower than the diurnal pH range. I. V. Hecker (**13**) points out that the excellent condition of the gums and teeth of the workers in pickling plants has been associated with an increased alkalinity of the saliva. That chewing paraffin or pure rubber increases salivary pH has been observed by Gies (**9**), Marshall (**21**), Starr (**31**), Henderson and Millet (**15**), Forbes (**8**), and others. It is with the results obtained from activation with substances that contacted and contaminated the secretions that the greatest confusion has occurred. For example, McClelland (**22**) reports that "Comparatively little or no influence was exerted on the pH of saliva when an orange, an apple, or a piece of dry bread was chewed." (But these data are undoubtedly the result of the experimental errors that are concomitant with the technique of expectoration.)

Despite the mass of controversial data that an investigation of the literature revealed, a re-examination of the results

in the light of our pH and quantitative studies points to much data which would give supporting evidence to the fact that the more rapidly flowing secretion is more alkaline than the more inhibited. We have demonstrated this parallel of pH and secretory rate of parotid secretion to hold regardless of the nature of the secretagogic agent or activating circumstances.

To find corroborating evidence for the hypothesis that qualitative variations may parallel secretory rate one must turn to the research of isolated glands. With the exception of Bramkamp's study these investigations have been with animals other than the human. Gregersen and Ingalls (**10**) noted that in dog's submaxillary saliva (resulting from chorda or pilocarpine stimulation) the Na concentration varies between 10 and 90 cc. of 0.1 N per 100 cc. of saliva, dependent closely on the rate of secretion. Werther (**37**) reported that the percentage of NaCl and of sodium carbonate varies directly with the rate of secretion. That the saliva is richer in solids when it is eliminated quickly by gradually increased stimulation, and in larger quantities than when the secretion is slower and less abundant, was reported by Heidenhain (**14**) and Werther. The fact that the amount of salts increases to a certain degree by an increasing rapidity of elimination was duplicated by Langley and Fletcher (**18**). Bramkamp (**2**) found that the protein nitrogen concentration of human parotid saliva increases progressively with increased secretion.

There is, however, some evidence which points to the fact that certain of the chemical constituents of saliva remain relatively unaffected by increased activation. Bramkamp (**2**) finds that despite the changes of the parotid protein nitrogen content, the protein content of mixed saliva changes but little with change of rate of secretion. Gregersen and Ingalls (**10**) note that the K content does not vary with the secretory rate and remains practically constant at the level of 10 to 20 cc. of 0.1 N per 100 cc. of saliva. Investigating the variations in the inorganic constituents of the dog's salivary secretions Baxter (**1**) observed that different stimuli (bread and meat powder, meat extract, NaCl, HCl, milk) acting in the mouth

cavity may produce from either the parotid or the mixed glands a flow of saliva of equal volume but of different inorganic composition.

The parotid secretion does not seem to be the only digestive secretion whose pH varies with its secretory rate. It has long been known that there is an almost invariable parallel relationship between the gastric acidity and rate of flow of the gastric juice. Pavlov (**25**) asserted that, "It is a rule almost without exception that the acidity of the juice (gastric) is closely dependent upon the rate of secretion; the more rapid the latter, the more acid the juice, and vice versa." This relationship was understood at first by Pavlov and his supporters and later by Hollander (**16**) in the light of Pavlov's hypothesis that the greater the quantity of juice the more rapidly will it flow over the stomach-wall, and therefore the less will it become neutralized. Thus it is their contention that the acid is formed within the parietal cell and is eliminated therefrom as a HCl solution of constant acidity, but the variations in acidity and corresponding changes in the neutral chloride content, are the result of neutralization by mucus within the stomach cavity. For obvious reasons such an explanation cannot be offered for the pH variations of the parotid secretion that we observed. Nevertheless, the results obtained from investigations of the reactions of both glands are so definitely quantitative that there can be little doubt that the mechanisms involved in the pH variations are rather simple physico-chemical reactions. What precisely are these processes remains for further research to decide.

In our investigation not enough cases have been studied to warrant a statistical analysis of the results. In evaluating the data, therefore, only those results which were well above the probable experimental error were regarded as significant. Yet, the relationship observed was so intimate as to permit a rather reliable prediction of the pH of the secretion from merely a knowledge of the rate at which it flowed when collected. Thus, if we know that during certain emotional states, such as, anxiety, fear, etc., there occurs a salivary inhibition we may justifiably deduce that at that time the

parotid secretion is more acidic than that secreted during the normal resting period. Or, on the other hand, in such states as that of good appetite, good health and so on, that is, in conditions in which the secretion has been shown to flow more abundantly, the secretion would tend towards a more alkaline pH. Our preliminary studies of such conditions have yielded data which have been in keeping with the relationship established in this report.

In view of the fact that there has been a good deal of dental research that points to the correlation of dental caries with acidic oral secretions (**26**, **28**), the implications for oral hygiene of the data here presented are obvious. It is of interest to note that at the July 1937 meeting of the American Dental Association McGonigle reported a relationship between dental decay and nervous upsets. Earlier, in 1934 Briggs (**4**) asserted that "the emotions of grief, worry, anxiety, or whatever may produce unhappiness or a depressed state of mind, seem to be factors that control either what has been termed the buffer substances in the oral fluids . . . or some change in the metabolism that is responsible for the occurrence of dental caries." Such observations are illuminated in the light of our previous quantitative studies and our more recent work with pH. These emotional states have been definitely shown to be accompanied by inhibited salivary secretions. The inhibited secretions have in turn been associated with a more acidic environment and thus perhaps with dental decay.

This study may also have an interesting neurological implication. Since the nature of the stimulation does not seem to be the determining factor of the quality of the secretion, it might serve as evidence for the hypothesis that there is a convergence of afferent paths upon the inferior salvitory nuclei from which a final common path of neural discharge is traversed. The principle of a 'final common path' may possibly be applicable to glandular, as well as motor or muscular activity.

Physiology, as well as other text books are still quoting as facts the erroneous data of earlier investigations. To take but one example, Stiles (**33**), in his *Nutritional Physiology*,

teaches that, "As it (salivary secretion) issues fresh from the glands it is slightly alkaline in reaction." In our experiments over a period of more than a year not one sample of inactivated parotid secretion as collected directly from the glands was alkaline in reaction.

Summary

In a prolonged series of experiments the variations in the pH of parotid secretion and rate of flow were determined under a number of conditions and with various secretagogic agents.

The secretion was obtained by means of attaching suction discs over the mouth of Stenson's duct, and was in most experiments collected from both glands simultaneously. The nature of the collection was such that the secretion at no time came into contact with the activating agents, organisms, or other factors within the oral cavity which may have altered its chemical consistency. The pH determinations were made electrometrically with the Beckman glass electrode pH meter.

Our data indicate a definite parallel relationship between the pH and secretory rate of parotid secretion. The more rapidly flowing secretions were more alkaline, whereas the slower rates were associated with a more acidic secretion. Regardless of the nature of the secretagogic agent used, the pH paralleled the rate of flow. The degree of acidity or alkalinity remained relatively constant provided the rate was uniform even though olfactory, gustatory, proprioceptive, or summated stimulation was used.

If one gland were activated more than the other, as in the case of unilateral stimulation, the pH of the more active gland was higher than that of the less active gland. In many cases an acid secretion was obtained from one gland while at the same time an alkaline secretion flowed from the other.

In preliminary studies of the effect upon parotid pH of prolonged mental activity, fatigue, sleep, or any state in which the glands are less active the secretion was found to be more acidic than that secreted during the normal resting state. In the conditions of good health, good appetite, etc., the more abundant secretion that is associated with these states have

been found to be more alkaline than the average normal secretion. A possible relation between these data and the recently reported studies of dental decay and nervous upset was suggested.

The data here presented might illustrate the physiological manifestation of a 'final common path' of neural discharge in glandular activity.

The diurnal variations of parotid pH seem to parallel the variations with the rate and previous activity of the gland. The secretion which accumulates in the alveoli of the glands after excessive activation is more alkaline than that which accumulates during periods of rest or salivary inhibition. The activation of the glands prior to collection of the secretion must therefore be considered in qualitative, as well as quantitative analyses.

With strong activation it was found possible to change the normally acidic parotid secretion into an alkaline secretion in less than one minute.

The average pH of the normal inactivated parotid secretions observed was 5.9. Challenging individual differences were obtained.

Inactivated secretions with a pH as low as 5.43 and activated secretions of a pH as high as 8.18 were obtained.

It would seem from these data that the factors which affect the quantitative variations of parotid secretion are to be considered in an understanding of the pH variations of that secretion.

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THE ONE-ERROR PER TRIAL METHOD OF MAZE LEARNING: HOW AFFECTED BY INSTRUCTIONS [1]

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Holmes and Carmichael,[2] in *An Experimental Study of Interrupted Partial Responses in Stylus-Maze Learning*, investigated Peterson's [3] 'completeness of response' theory as a determining factor in motor learning. Using thirty human subjects and a modified Cameron [4] circuitous stylus maze, they found that the group with interrupted responses was superior to the control group in terms of errors. They concluded that 'completeness of response' was not a factor determining learning and accounted for their results in terms of a greater intensity of response introduced by the interruptions. This explanation was the one offered by Lewin and Zeigarnik [5] in accounting for the better memory of their subjects for interrupted tasks than for tasks which were not interrupted.

The present writer, before seeing the above summary, had obtained results which seemed contradictory to these. Since then, he has had the privilege of borrowing the Holmes and Carmichael manuscript from the Brown University Library, and has done further experimenting in an attempt to account for differences in the two sets of findings.

[1] An abstract of part of this paper was given at the American Psychological Association meeting in 1936.

[2] A summary of this study is published in the *Proc. and Papers Ninth Internat. Congress of Psychol.*

[3] Peterson, J., Completeness of response as an explanation principle in learning. *Psychol. Rev.*, 1916, **23**.

[4] Cameron, N., Cerebral destruction in its relation to maze learning. *Psychol. Monog.*, 1928, Whole No. 177, **39**.

[5] Lewin and Zeigarnik's work is discussed in the following article: Brown, J. F., The methods of Kurt Lewin in the psychology of action and affection. *Psychol. Rev.*, 1929, **36**.

Five hundred subjects, divided into seven groups, three experimental and three control, learned U-type finger mazes. Two of these groups (75 *Ss* each), one experimental and the other control, learned a 10-alley maze, two (60 *Ss* each) an 18-alley maze, and two (80 *Ss* each) a 21-alley maze. The seventh group (70 *Ss*) learned the same 18-alley maze, but learned it under slightly different conditions, and can neither be properly classified as experimental nor as control.

Each pair of comparable groups were equalized for sex differences, the number of men and the number of women being about the same in the two groups. Intelligence was also eliminated as a factor, the average centile rankings of each pair of comparable groups being practically equal. These sex and intelligence comparisons are given in Tables 1, 2, 3 and 4. The difference in the average centile ratings is given in the column on the right and with three exceptions the differences are less than one-tenth of one

TABLE 1

10-ALLEY MAZE

One Error Method		Whole Method		Dif. in Ave. Centile Ratings
Group 1 N—75 (74)		Group 2 N—75		
Total	Ave. Centile—57.07	Total	Ave. Centile—57.04	.03
31 Men	" " —58.28	31 Men	" " —58.19	.09
44 Women (43)	" " —56.21	44 Women	" " —56.23	.02

TABLE 2

18-ALLEY MAZE

One Error Method		Whole Method		Dif. in Ave. Centile Ratings
Group 3 N—60 (59)		Group 2 N—60 (58)		
Total	Ave. Centile—58.37	Total	Ave. Centile—58.41	.04
33 Men (32)	" " —53.56	32 Men (30)	" " —53.33	.23
27 Women	" " —64.07	28 Women	" " —63.86	.21

TABLE 3

21-ALLEY MAZE

One Error Method		Whole Method		Dif. in Ave. Centile Ratings
Group 5 N—80 (78)		Group 6 N—80 (78)		
Total	Ave. Centile—58.35	Total	Ave. Centile—60.33	1.98
34 Men (32)	" " —51.63	37 Men (36)	" " —51.60	.03
46 Women	" " —63.02	43 Women (42)	" " —63.00	.02

TABLE 4

18-ALLEY MAZE (TIME DIFFERENCE)

Whole Method (60 secs.)		Whole Method (15 secs.)		Dif. in Ave. Centile Ratings
Group 4 N—60 (58)		Group 7 N—70		
Total	Ave. Centile—58.41	Total	Ave. Centile—58.44	.03
32 Men (30)	" " —53.33	36 Men	" " —53.36	.03
28 Women	" " —63.86	34 Women	" " —63.82	.04

centile. (A few *Ss* used in the first part of this experiment had no centile ratings.) The numbers in parenthesis indicate the actual number of *Ss* on whom the centile averages were based.

The two groups learning the 10-alley maze were given the usual [6] maze instructions. The other five groups, however, were given additional instructions as follows: (1) each *S* was shown a 6-alley maze and was informed that it was of the same unit structure as the one he was to learn; and (2) he was told what was considered to be the best method for learning mazes and was asked to use it. This method was described as that of learning the maze in a verbal manner, that is, of memorizing and grouping according to direction the successive moves. It was pointed out that when a person has learned a maze in this manner, he has a series of numbers in mind, such as 2-1-3-2, etc., corresponding to the pattern of the maze, and that it is not necessary to remember rights and lefts, since a break in the numbering means a change in direction.

The differences between the experimental and the control groups were as follows:

First, in the experimental groups, the subject stopped as soon as he made an error and after a short time interval began again at the starting point. In the control groups, the subject went all the way through the maze each trial regardless of the number of errors made. In other words, the experimental groups used what has been called the *one-error method*, while the control groups used the *whole method*.

Second, in the experimental groups the time interval between trials was about 15 seconds, whereas in the control groups it was about one minute.

Results

The comparisons between the two methods of maze learning are offered in Tables 5, 6 and 7. These results are given in

TABLE 5
10-Alley Maze

	One-Error Method Group 1 N—75		Whole Method Group 2 N—75		$\sigma_{diff.}$	$\frac{Diff.}{\sigma_{diff.}}$
	Mean	σ	Mean	σ		
No. of errors.....	45.65	24.56	37.71	20.50	3.69	2.15
Time (secs.).....	1038.28	552.16	868.00	443.83	81.80	2.08

TABLE 6
18-Alley Maze

	One-Error Method Group 3 N—60		Whole Method Group 4 N—60		$\sigma_{diff.}$	$\frac{Diff.}{\sigma_{diff.}}$
	Mean	σ	Mean	σ		
No. of errors.....	27.45	10.68	44.38	21.43	3.09	5.48
Time (secs.).....	822.12	312.68	1080.58	511.28	77.37	3.34

[6] Scott, Thurman C., The retention and recognition of patterns in maze learning, this Journal, 1930, **13**, p. 168.

TABLE 7

21-ALLEY MAZE

	One-Error Method Group 5 N—80		Whole Method Group 6 N—80		$\sigma_{diff.}$	$\frac{Diff.}{\sigma_{diff.}}$
	Mean	σ	Mean	σ		
No. of errors.....	42.78	22.48	75.80	49.63	6.09	5.42
Time (secs.).....	1293.00	633.43	1356.19	660.25	102.30	.62

TABLE 8

18-ALLEY MAZE

	One-Error Method Time Interval—15 secs. Group 3 N—60		Whole Method Time Interval—15 secs. Group 7 N—70		$\sigma_{diff.}$	$\frac{Diff.}{\sigma_{diff.}}$
	Mean	σ	Mean	σ		
No. of errors.....	27.45	10.68	58.50	49.46	6.08	5.10
Time (secs.).....	822.12	312.68	1035.60	523.37	63.95	3.34

TABLE 9

18-ALLEY MAZE

	Whole Method Time Interval—60 secs. Group 4 N—60		Whole Method Time Interval—15 secs. Group 7 N—70		$\sigma_{diff.}$	$\frac{Diff.}{\sigma_{diff}}$
	Mean	σ	Mean	σ		
No. of errors.....	44.38	21.43	58.50	49.46	6.54	2.16
Time (secs.).....	1080.58	511.28	1035.60	523.37	90.94	.49

both errors and time. In Table 5 where the 10-alley maze was learned under the usual maze instructions the whole method seems superior in errors and time. This superiority is not completely reliable statistically, but approaches such reliability, the chances being 98.4 in 100 for errors and 98 for time. In Tables 6 and 7, however, where the other two mazes were learned with additional instructions, the one-error method is found to be superior. This superiority is completely reliable in errors and time for the 18-alley maze and in errors, but not

in time, for the 21-alley maze. (Tables 8 and 9 will be referred to later in the paper.)

Discussion

Holmes and Carmichael's results are contradictory to those obtained with the 10-alley maze, but support those obtained with the 18- and 21-alley mazes. Their written instructions are rather similar to those used with the 10-alley maze and are not as full and clear as those used with the other two mazes. They did, however, show their *S*s a sample maze, and this seems to have made their total procedure more similar on the whole to that used with the 18- and 21-alley mazes than to that used with the 10-alley maze. This, then, would seem to indicate that there is no real or serious contradiction between the results of the present experiment and those of Holmes and Carmichael.

There may be another factor operating here to lessen this contradiction also, and that is, that the maze used by Holmes and Carmichael seems to be an easier maze than even the 10-alley maze used in the present experiment. It has only nine alleys. Also, it is of a circuitous type—a type which is rather easily solved by the use of visual imagery. With a more difficult maze, with instructions which are less full, and using the one-error method, the subject is forced to flounder about for quite a while before he has an opportunity to learn anything. This point will be referred to again later in the paper. This near agreement, then, indicates that in this experiment, as well as in that of Holmes and Carmichael, completeness of response is not a factor which determines learning.

As mentioned before, Holmes and Carmichael explained their results by Lewin and Zeigarnik's principle of intensity, stating that intensity was due to the suddenness with which the *S* was stopped in a blind alley and to the movement of his hand back to the entrance of the maze. Evidently, this intensity factor, or whatever factor may be introduced by an interrupted response, must have influenced the results of the present experiment. It seems, however, that intensity is due

to more factors than suddenness and change. There is recency and the singleness or simplicity of the attention stimulus. The error is always the last part of the movement made, the most recent part, and is a much simpler situation on which to center the attention than that where several errors are made and attention is scattered over all of them.

Intensity, though, is not the single, all-important factor operating here, else the one-error method would have also been superior on the 10-alley maze where the usual instructions were given, as well as on the other two mazes where fuller instructions were used. This difference, which the intensity factor does not explain, can probably be accounted for only in terms of the difference in the instructions used in these two situations. When the one-error method is used in the first situation, the instructions are not full enough for the *S* to comprehend fully what he is doing. He does not know the construction, the unit analysis, of the maze, and cannot profit greatly by his errors, since he has very little idea how he makes them. He frequently makes the same error repeatedly before it is eliminated. He also has the feeling of pushing ahead blindly, not knowing where the goal is and not having anything to aim at. He continues for some time in about as great a state of ignorance in regard to the nature of the maze as the *S* using the whole method is in on the first trial. With the one-error method, no goal gradient can be built up. There can be no backward elimination of alleys, and no anticipatory goal reactions are possible. No strong Gestalts can be easily and quickly developed in the maze pattern, insight has little chance, and there is very little reward until the total path has been learned. The *S* using the whole method, however, after the first trial or two has a rather correct idea in regard to where the goal is and has a general notion of how to get there. He no longer is indulging in pure guess work in regard to which turns to take, even though he may have very little notion of the unit structure of the maze. The knowledge of the position of the goal gives him something to aim at. It also enables him to get a clearer picture of the pathway than is possible for the

subject who uses the other method and does not have this goal knowledge.

In the second type of situation, however, where further instructions are given, the subject knows what the unit structure of the maze is before he makes his first trial. He also knows what method of learning he is to use. All he has to do is to work out his number system, and this can be accomplished more economically if small sections of the maze are taken at a time. The average *S* using the whole method cannot remember all the moves in an 18- or 21-alley maze the first time or two that he goes through it. As a rule, the more he tries to remember beyond a certain amount, on the first run or two, the less he actually remembers and of course he is piling up errors on every run. The one-error method, then, seems ideal for this type of maze learning situation. The *S* doesn't go very far, as a rule, until he makes an error and, thus, is forced to limit his attention to one error and to small sections of the maze at a time. It is entirely possible for errors to be eliminated without being repeated, and very few are repeated by the best *S*s unless they are unfortunate enough to 'luck' through larger sections of the maze on any one trial than they can remember.

With fuller instructions, then, in regard to the unit construction of the maze and in regard to the best method for learning this type of maze, the *S* gets along just about as well or possibly better without goal knowledge than with it. With goal knowledge there is a tendency for the *S* to be looking ahead, and thus possibly concentrating less than he should on the pathway which he is at the moment traversing.

A question might be raised at this point as to why the time scores of the two groups learning the 21-alley maze are so nearly the same when there is a reliable difference between those learning the 18-alley maze. It should be remembered that a 21-alley maze is more difficult in proportion to its length than is an 18-alley maze and this additional difficulty is probably more noticeable in time with the one-error method for the following reason. With the whole method, part of the maze can be learned in a motor manner. This is particularly

true of the last part which may be learned backward from the goal while the first part is being verbalized in a forward direction. With the one-error method, on the other hand, all of the maze must be verbalized and grouped, step by step, in the forward direction. The last few number combinations must be the last ones learned and are the most difficult, since what has been learned up to this point has already become a rather heavy memory load. This has a tendency to slow the *S* down more and more as he approaches the end and causes his last runs to be the slowest of all.

It seemed possible that the difference in the time intervals introduced between trials (15 seconds in the experimental and 60 seconds in the control groups) might have had some effect upon the results. A partial answer to this time question is given in Tables 8 and 9. In these tables groups 3 and 4 are compared with group 7, a group which, using the whole method, learned the 18-alley maze with a 15-second interval between trials. In Table 8 where group 3 is compared with 7, the time interval of 15 seconds is the same for both groups, the only difference being that group 3 used the one-error method, and group 7 the whole method. The difference between these two groups is completely reliable for both errors and time. When this table is compared with Table 6, a table in which groups 3 and 4 are compared, it is found that the standard scores of the difference for errors and the standard scores of the difference for time in the two tables are practically the same, indicating that the change in the time interval from 60 seconds to 15 seconds with the whole method has produced no noticeable effect. In Table 9, however, where groups 4 and 7 are compared, both groups using the whole method, but one using a 60- and the other a 15-second time interval, it looks as through the 60-second time interval is probably better for errors. The chances are 98.5 in 100 that the 60-second time interval is better than the 15-second interval. When it comes to time, however, the 15-second interval seems to be slightly the better of the two and, taking the two tables together, the only safe conclusion is that with the whole method a change

from a 60- to a 15-second interval probably does not affect the results.

This does not enable us to be very certain in regard to what would happen if the time interval in the case of the one-error method should be changed from 15 to 60 seconds. It seems highly probable, though, that an enforced interval of 60 seconds might prove distracting, since there is so much less that is new to be reviewed and fixated than in the case of the whole method.

It would also be unwise to draw any very definite conclusions in regard to what effect any change in the time interval would have in the case of the 10-alley maze where instructions are less full. Once more, however, it would seem reasonable to believe that about the same would happen here as in the case of longer mazes and the fuller instructions. But whatever the effects of any such changes in time intervals might be, they would hardly eliminate the differences found in this study. In other words, the evidence seems to indicate that the difference in the two methods of learning mazes and the difference in the two sets of instructions are more important than the difference in the two time intervals.

Summary

1. In learning a 10-alley maze with the usual instructions, the whole method of learning was slightly superior in errors and time.

2. In learning the 18- and 21-alley mazes with fuller instructions, the one-error per trial method was decidedly superior in errors and slightly superior in time.

3. Lewin and Zeigarnik's intensity factor introduced by the interruption and by the simplicity of the attention stimulus seemed to be one reason why the one-error per trial method was superior with the longer mazes.

4. The fuller instructions, however, seemed to be an important factor in causing the one-error method to be superior. The fuller instructions seemed to be a complement to the intensity factor. Without them, intensity did not seem to operate.

5. In this experiment Peterson's 'completeness of response' did not seem to be a factor determining learning.

6. The difference in the time intervals accompanying the two methods of learning did not seem to be a factor of much importance. In other words, the difference between the two methods of learning and the difference between the two sets of instructions were much more important in this experiment than was the difference between the two time intervals.

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VERBAL GESTALT EXPERIMENTS WITH CHILDREN

BY H. L. HOLLINGWORTH

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In an earlier article on the conditions of verbal configuration [1] college students were required to make up words out of disarranged letters which were sometimes presented in such a form as to make other words (gestalted) and sometimes in non-sense arrangement. The question was whether or not the existing word exercised a constraint on the manipulation of its component letters in the making of another word (which was always to be the name of an animal).

No evidence was found that the verbal gestalt exercises such constraint; instead some indication was found that the brighter students profited by such an arrangement. It was left "an open question whether positive results might not be secured with duller or younger subjects."

We have now repeated the experiment on a bright young group of 46 subjects, aged 8 to 10, with intelligence quotients ranging from 120 to 197. Data are available to show that age for age the two groups have about the same I.Q. or centile standing in their own age population; that is, they are about equally bright. But the children meet both our earlier requirements, in that they are younger and would make lower scores on intelligence tests suitable for both groups.

The material was presented in two forms or lists. A word that appeared gestalted in one list was presented un-gestalted in the other. Thus each list contained all fifty words, half gestalted and half not. Form C was used with 24 subjects, and form D with 22, the two groups being the children in two classes for the bright in P.S. 500, Manhattan, New York City, an experimental school established in coöperation with Teach-

[1] This JOURNAL, 1935, 18, 299–306.

ers College. After the instructions, 15 minutes were allowed for work.

We consider first the influence of the two forms of stimulus presentation on the total group of subjects, in the two test forms C and D. The following Table shows the total number of words correctly solved in each case.

Form	Cases	Gestalted	Ungestalted	Total
C	24	42	48	90
D	22	52	26	78
Total	46	94	74	168

In Form C a few more ungestalted words are handled. Five subjects have more of the gestalted, 12 more of the ungestalted, the remaining 7 subjects showing no difference. That is, the ungestalted forms were handled better in just half of the cases.

In form D just twice as many gestalted words were handled as ungestalted (52 and 26), and this was the case with 16 of the 22 subjects; only 1 subject showed the reverse relation, the remainder (5) showing no difference.

All in all, 94 words were made from the gestalted material and only 74 from the ungestalted. That is to say, instead of the constraining effect of a verbal gestalt appearing more striking with younger subjects, just the opposite effect is clearly present.

With college students, Form D was found more difficult, although the two forms were expected to be equal in this respect. With these two small groups of children, comparison is not very reliable, since exceptional ability might appear unequally in the two groups. But there are indications that here also Form D is more difficult.

With Form C the range of scores is from 0 to 12; for Form D the range is from 0 to 9. The average score for C is 3.75 words, for Form D 3.54 words. The median score is 3 in both forms; there was only one zero score for C, while for D there were two. On the whole then, form D is again shown to be slightly more difficult.

The difference between gestalted and ungestalted presentation appears interestingly when different groups of words are considered. Of the 50 words, 31 were solved by at least some one child. Some of the words are clearly easier than others, as shown by the number of children solving them. In general, as the following Table shows, the gestalted presentation is more favorable the easier the words are. If all the words solved are considered, the gestalted presentation has only slight advantage (15 to 13). But if words are considered which were solved by at least 10 of the 46 children, four times as many are solved in the gestalted form.

Frequency of Solution	Number	Gestalt Favorable	Gestalt Unfavorable	No Difference
All words solved by at least one child.....	31	15	13	3
Done more than once in any one form.....	22	12	8	2
More than twice in any one form.....	17	10	5	2
More than four times in both forms together.	13	8	4	1
By over 10 of the total 46 children.....	5	4	1	0

Since requests have been received for the precise list of stimulus materials used in the earlier experiment, and now used again, the material is here printed. The first column gives the key words. Then come the letters as presented in Form C, with the number of children solving each word, and the last two columns give the letters as presented in Form D, with the number of solutions for each word. The instructions, at the top of each sheet, were as follows:

"All these are the names of animals, with the letters disarranged. Thus of CUB KOLL you can make the work BULLOCK; of MECLA you can make the work CAMEL, and so on. Opposite each, write the correct name of the animal, using all the letters given, and no others. Do as many as you can in the time allowed. If some seem difficult at first, pass over them and come back to them later if you have time."

In the case of the college students, the advantage of the gestalted presentation appeared only with those with the very highest Alpha Test scores. We may make a similar analysis of the present results by dividing each group into sub-groups of lower and higher I.Q. since the age range was only 8 to 10 years (except for two cases 7 and 11) and the median age for both groups was the same (9 years). We then have for Form C a lower and a higher I.Q. group, and likewise for Form D, although even the group here called 'lower' is a relatively bright group, with median I.Q. of 137. The high group has a median I.Q. of 152.

STIMULUS MATERIALS USED

Word	Form C	Score	Form D	Score
tadpole	leap dot	0	lpae odt	0
oyster	soetyr	0	storey	0
grasshopper	gopher spars	3	gpoerh psrsa	0
badger	rga bde	5	rag bed	1
rabbit	bat rib	13	bta ibr	0
spaniel	lnea spi	0	lean sip	0
gnat	tang	7	tnga	1
sparrow	por arws	0	pro wars	0
beetle	eel bet	6	ele tbe	2
blackbird	bdal rbkci	0	bald brick	0
silkworm	slim work	0	siml wrok	0
greyhound	yungo hrde	0	young herd	10
chamois	his moca	0	hsi maoc	0
reindeer	ndee reri	3	need rire	0
salmon	no alms	1	no asml	0
horse	soher	7	shore	9
bobolink	look nibb	1	loko bnib	0
butterfly	tbuyr fetl	0	truby felt	0
kangaroo	ago koran	4	aog krnoa	1
rattlesnake	setel ta aknr	0	steel at rank	0
sardine	ran side	0	rna sedi	0
buffalo	falo fbu	8	foal fub	1
catterpillar	trailer clap	0	tlirrea cpla	0
tortoise	rsei otot	0	rise toot	0
weasel	see awl	2	ese wal	2
peacock	a copekc	6	a copeck	15
whale	he law	2	eh wal	9
leopard	odl epra	4	old pear	5
insect	nicest	0	ncites	1
turkey	tyr kue	5	try uke	1
lioness	sole sin	0	selo nis	2
elephant	plae hnts	3	peal then	3
magpie	aim peg	0	ami epg	2
flounder	fulo dner	0	foul rend	0
muskrat	ark smut	1	akr mtsu	1
donkey	on ykde	1	on dyke	3
falcon	clan of	0	canl fo	0
oriole	oli reo	0	oil ore	0
hornet	rent oh	0	rnte ho	1
lizard	rza ldi	3	raz lid	12
ostrich	shirt co	0	sriht oc	2
serpent	rste pne	0	rest pen	0
lambkin	am blink	0	am lbnki	1
lobster	rbo ltse	1	rob lest	0
crane	rance	2	rnaec	0
dragon	gdo rna	0	god ran	0
codfish	chids of	0	cihsd fo	1
kitten	ti ektn	0	it kent	0
locust	oculs	1	ousctl	0
chicken	hci nkec	1	hic neck	2
	Totals	90		78
	Words solved	24		23
	Gestalted 12		10	
	Ungestalted 12		13	

When thus divided, it appears that Form C was used by 14 of the lower and 10 of the higher group; form D was used by 9 of the lower and 13 of the higher group. Since more of the low group used the slightly easier Form C, and more of the high group the slightly more difficult Form D, the effect of I.Q. will actually be somewhat more rather than less than that experimentally found. But the division of the two forms and the two groups was as nearly balanced as was experimentally possible.

The data from these comparisons are as follows:

	B Group, Lower I.Q.		A Group, Higher I.Q.	
Range of I.Q.		120–142		143–197
Median I.Q.		137		152
Median age		9		9
Total words done		59		108
Gestalted	30		65	
Ungestalted	29		43	
Median number of words		2		4
Range	0–8		0–12	

As the fore-going Tables shows, the higher I.Q. group solves 83 percent more words than the lower group (108, 59). Since the ages were the same, this effect must be related to relative intelligence.

Gestalted presentation has no reliable effect on the lower I.Q. group, the scores being 30 and 29 for gestalted and ungestalted forms. In 6 only of this group the gestalted form resulted in a larger number of words formed.

But for the higher I.Q. group, gestalted presentation is definitely favorable, the two scores being gestalted 65, ungestalted 43. In 14 of the 23 cases in this group this relationship holds. With the higher I.Q. group gestalted presentation yields 51 percent more words solved.

These results only confirm those from college students. In both groups the brighter ones profited from having the letters presented in word form, although these word forms were quite irrelevant. We must conclude that using younger subjects fails to reveal the word form as exercising any constraint on the free manipulation of its component letters. Again we find no indication that the word obeys the laws ascribed to 'gestalten.'

We conclude as before, that if anything is going to obey the alleged 'laws of gestalten' a word ought to. And words do not. But words beautifully exemplify those actual experiences and modes of behavior which the gestalt laws have been spun to camouflage. The gestalted form apparently offers very slight cues in the way of syllabification, and it at least presents one organization that is to be discarded, since it is not the name of an animal. From these very slight cues the very bright are able to profit.

(Manuscript received February 8, 1938)

AN EXPERIMENT IN GENERALIZING: A UNICURSAL PROBLEM (1)

BY JAMES L. GRAHAM

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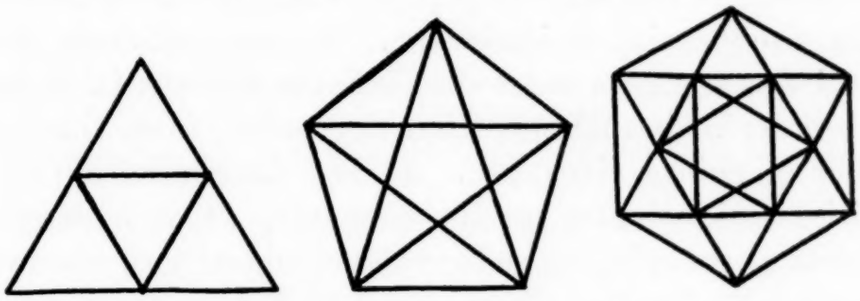
The problem was derived from the familiar puzzles of tracing geometric figures without lifting the pencil from the paper, crossing, or retracing lines. The task assigned was the discovery of generalizations of the major premise type and not the ability to trace unicursally the forty-eight figures presented. Success typically involved not a single but a series of discriminative acts. Three good generalizations and a poorer one were discovered. These are: 1. Any figure which has no odd branchings at any point can be traced unicursally, starting at any point. 2. Any figure which has two and only two odd branchings can be traced unicursally, if the start and end occur at the odd branchings. 3. Any figure which has more than two odd branchings can not be traced unicursally. 4. The poorer principle described a method of tracing figures and contained two or three elements, namely, a method of grouping the complex figures into n unicursal paths, a method of proceeding sequentially from one such path to another adjacent unicursal path, and a method of avoiding the improper closing of the adjacent unicursal path. There were greater difficulties in stating the fourth principle in universal terms and in expressing it clearly. Since it was scored more liberally and was closer to the more habituated task of discerning one's ability to trace the complex figures, it has been analyzed separately.

The procedure used follows: A fore-exercise was presented orally to illustrate four types of discriminative acts logically involved in the discovery of such generalizations. It discussed quite a different problem from the unicursal one, namely, the discovery of a shortcut method of squaring numbers ending in five. The unicursal problem was presented

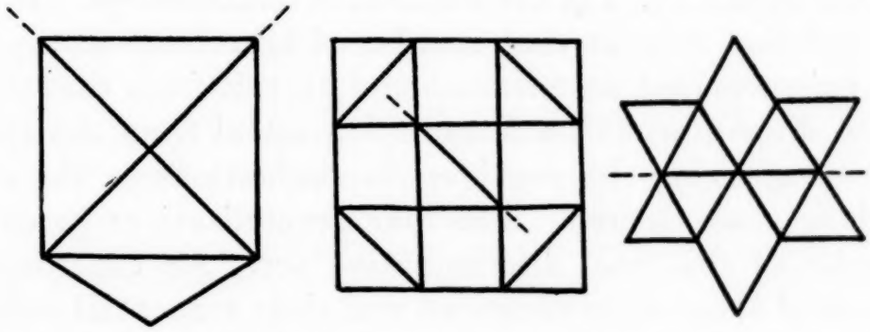
in written form. It described the familiar puzzle situation, and presented and partially analyzed forty-eight figures grouped into a set that could be traced unicursally beginning at any point, a set that required starting at designated points,

FIG. I. Such figures can be traced unicursally, starting at any point.



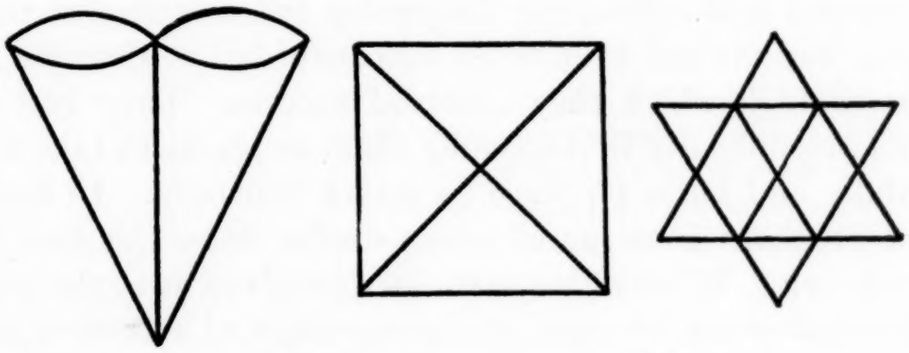
Lines 9	Lines 20	Lines 42
Points 6	Points 10	Points 18
Branchings 3(2's) 3(4's)	Branchings 10(4's)	Branchings 12(4's) 6(6's)

FIG. II. Such figures can be traced unicursally, if start is made at a dotted line.



Lines 10	Lines 25	Lines 22
Points 6	Points 16	Points 13
Branchings 1(2) 2(3) 3(4)	Branchings 4(2) 10(4) 2(5)	Branchings 6(2) 4(4) 2(5) 1(6)

FIG. III. Such figures cannot be traced unicursally.



Lines 7	Lines 8	Lines 22
Points 4	Points 5	Points 13
Branchings 3(3) 1(5)	Branchings 4(3) 1(4)	Branchings 6(2) 3(4) 4(5)

and a set that could not be traced unicursally. The students worked on the task for thirty minutes in groups of 38 to 40. The four types of discriminations pointed out in the fore-exercise, with an illustration taken from the unicursal problem instead of from the fore-exercise, are given below: 1. The discernment of crucially important variables from those that are inconsequential or irrelevant. It seems obvious that to succeed the students must discriminate the crucial influence of the order of branchings from any point, from that of the number of points, lines, etc. 2. The discrimination of uniformities amid diverse specific elements. This is essentially a process of grouping to reduce the complexity of the task to discriminative levels. On the page of figures which could be traced unicursally, starting at any point, the order of the branchings from any point were, 2, 4, 6, or 8. These could be grouped under the common description of 'even branchings' at every point. 3. The discernment of relationships. It may be noted that with an even number of branchings at a point, each pair provided an entrance and an exit from that point. 4. The discernment of a formulation useful from the standpoint of applying the previous discriminations to the characteristic goals desired. The four generalizations listed are examples of this final discriminative act. An experimental analysis of these discriminations and their sequential order in discovering relationships, is hampered by the fact that these discriminations are not regularly available as part scores and are not meaningful as separable generalizations until they culminate in the formulation of a useful procedure relative to the desired goal. Students frequently fail to verbalize these discriminations and even when successful fail to describe the steps through which they achieved success. They customarily have difficulty in discerning them as places to take hold planfully and know no place to attack fruitfully. In fifteen other problems constructed along similar lines, this fact has been shown. When no suggestions were given as to the types of discrimination involved, the percentages of success were a third to a fifth less than in this task where they were illustrated in a fore-exercise (**2**). Results: Fifty-five percent of 152

students learned one or more of the good generalizations listed above, and seventy-seven percent succeeded if all four principles are included. As a group, they averaged better than one 'good' generalization apiece, and 1.35 per student when all four principles are included. Correlation with the

TABLE I

COMPARISON OF GENERALIZATIONS AND SCORES ON THE A.C.E. EXAMINATION

Generalizations	A.C.E. Quartiles				A.C.E. Deciles	
	Q_1	Q_2	Q_3	Q_4	1	10
	Percentages of individuals succeeding					
1, 2, and/or 3	17	23	27	32	2	16
4 only	38	31	15	15	31	7
None	26	25	32	17	10	0
None and 4	33	28	23	17	20	3
	Percentages of generalizations offered					
1, 2, and/or 3	19	20	27	34	2	17
4 only	33	32	15	20	23	7
1, 2, 3, and/or 4	22	23	24	31	6	16

TABLE II

COMPARISON OF GENERALIZATIONS AND PSYCHOLOGY GRADES

	Grade Quartiles				Grade Deciles	
	Q_1	Q_2	Q_3	Q_4	1	10
	Percentages of individuals succeeding					
1, 2, and/or 3	21	22	24	33	7	13
4 only	29	31	27	13	9	5
None	28	28	26	18	17	8
None and 4	29	28	27	16	13	7
	Percentages of generalizations offered					
1, 2, and/or 3	21	20	23	36	7	15
4 only	29	24	32	15	9	6
1, 2, 3, and/or 4	23	25	25	28	8	13

The generalization numbers are those used in the text of the article. The numbers in the table represent distribution percentages not absolute scores, and these have all been equated for the size of the groups.

A.C.E. Examination was + .43 using only the first three principles, and + .37 using all four. Correlation with psychology grades was + .27 for three principles, and + .33 for four. Critical levels are probably more significant. Thus a comparison of the highest and lowest deciles, after equating for the size of the groups, shows eight times as many generalizations and successful individuals in the highest decile of the A.C.E. Examination, but only twice as many in the highest decile in grades.

Motivational factors present a serious difficulty in these tasks, since failure is recognized by the student until a useful formulation has been completely acquired. Students are observed to show marked individual differences in the time and effort expended before they reject the assignment or substitute for the generalizing task one of getting specific answers such as learning to trace particular figures unicursally. The difficulty of finding suitable part scores for analyzing the amount of frustration a student will bear before quitting or diverting his interest from the task, hampers an attack upon this problem. However, the situation here is much simplified over the usual adjustment and personality situations, where this problem assumes practical importance. A similar absence of meaningful and constant part scores, since only full success or complete failure is scorable, hinders the analysis of the higher learning processes involved in the discovery of generalizations of this major type. However, the isolation of tasks that are essentially discriminative from other learning types should have some possibilities for fruitful research. Our educational programs and procedures have too long neglected the development of skills in discriminating and generalizing, through an over emphasis upon the application of generalizations as a means of securing specific answers. The improvement of guidance methods and knowledge of the prerequisite skills are, therefore, most desirable.

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THE EFFECT OF ELECTRIC SHOCK ON LEARNING IN EYE-HAND COÖRDINATION

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Introduction

The introduction of punishment in various forms in the performance of tasks involving learning has had various effects on the rate and amount learned. Some investigators, including Thorndike (**10**), Lorge (**8**), Muenzinger (**9**) and Tuckman (**14**), found that certain forms of punishment were detrimental to learning. Other investigators, including Barlow (**1**), Bunch and McTeer (**2**), Crafts and Gilbert (**3**), Jenson (**6**), Discerens and Vaughn (**4**), found that the administration of electric shocks facilitated learning in certain situations. Johanson's results (**7**) indicated that the administration of electric shocks produced shorter reaction times because a state of keener attention was produced. Tolman, Hall and Bretnall (**11**) in using electric shock on the human subject in the punch board maze found that where the stimulus (bell or shock) emphasized the correct response, learning was facilitated and where the wrong response was accented or emphasized a condition unfavorable to learning was produced. These authors suggested that any violent negative emotional stimulus, such as electric shock, coming in immediate sequence upon either the right or wrong response, will tend to disrupt learning. Gurnee (**5**) in a recent study of the effect of electric shock on right and wrong responses using the bolthead maze found that light shock for either right or wrong responses and moderate shock for wrong responses were better than no shock, and no shock was better than moderate shock on right responses. The most effective condition was light shock on right responses and the least effective was moderate shock on right responses. Light shock on wrong responses was more effective than moderate

shock on wrong responses. All these differences, however, were small and the critical ratios indicated doubtful statistical significance.

Procedure

The main purpose of this study was to determine the effect of electric shock on motor learning in eye-hand coördination. The apparatus used was a specially designed manual pursuit-oscillator which has been described in more detail in previous reports (12) (13).

The learning task was to hold a flexible stylus on an insulated moving target which oscillated in front of the standing subject at the rate of one oscillation per second. The target was a silver disc 12 mm in diameter sunk flush in a piece of bakelite about 15 cm by 20 cm. The gravity-type stylus held by the subject would not permit any greater pressure than its own weight on the target. An electric counter was activated and the 60-cycle tone in a watch-case receiver could be heard whenever the stylus was in contact with the target. Each subject was given a brief preliminary trial and instructions to acquaint him with the task.

This study constituted three different experimental situations using three different groups of college men. Nine consecutive trials were given each subject in each group. Each trial was *one minute* in duration with rest periods of *three minutes* between trials for all three experimental situations.

In the first experimental situation (17 subjects), electric shocks were not administered and the attempt was made to obtain the normal learning curve for this particular type of eye-hand coördination with the one-minute trials alternating with the three-minute rest periods. The task was self motivating in that as long as the individual held the stylus on the oscillating target the 60-cycle tone from the watch-case receiver could be heard.

In the second experimental situation (11 subjects) each subject received a continuous series of electric shocks from the inductorium (DuBois-Reymond) whenever the stylus lost contact with the target. This was accomplished by having a copper handle on the stylus which was held by the right hand and in the left hand was held a brass cylinder electrode completing the circuit in the secondary of the inductorium. To avoid receiving a continuous series of electric shocks the subject must hold the stylus on the oscillating target continuously.

In the third experimental situation (27 subjects) each individual received no shocks during trials 1, 3, 5, 7 and 9; but received shocks during trials 2, 4, 6, and 8 whenever the stylus lost contact with the target. Therefore, during alternating trials the subject received electric shocks unless he were able to keep the stylus on the target continuously. This, of course, was impossible especially in the early trials and some subjects received shocks about half the time in the later trials. No subject ever received a perfect score for any one of the nine trials. Each subject was informed just before each trial whether he would receive shocks during that trial.

The strength of the electric shock was not held constant from subject to subject because some subjects could not feel the shocks which were rather severe punishment for others. Therefore, each subject in the experiments where shocks were used was tested empirically as to the setting of the inductorium so that the shock would be severe enough to produce rather marked tingling sensations in the hands and wrists, but not severe enough to produce excessive contraction in the forearms.

We were interested primarily in the method of the third experimental situation, namely, alternating trials with electric shocks and without electric shocks; and comparing the gains made during the trials with shocks with the gains made during trials without shock. This procedure permits a progressive comparison of trials with shock and trials without shock as learning takes place in the same subject in one experimental sitting.

A short questionnaire on the psychological effects of the electric shock was filled in by each subject. The questions pertained to whether or not the subject was afraid of, annoyed by, or objected to the electric shock.

Experimental Results

Table 1 gives the average scores for each trial for the three experimental groups, namely, Situation I normal learning or control group, Situation II electric shock each trial and Situation III electric shock alternating trials.

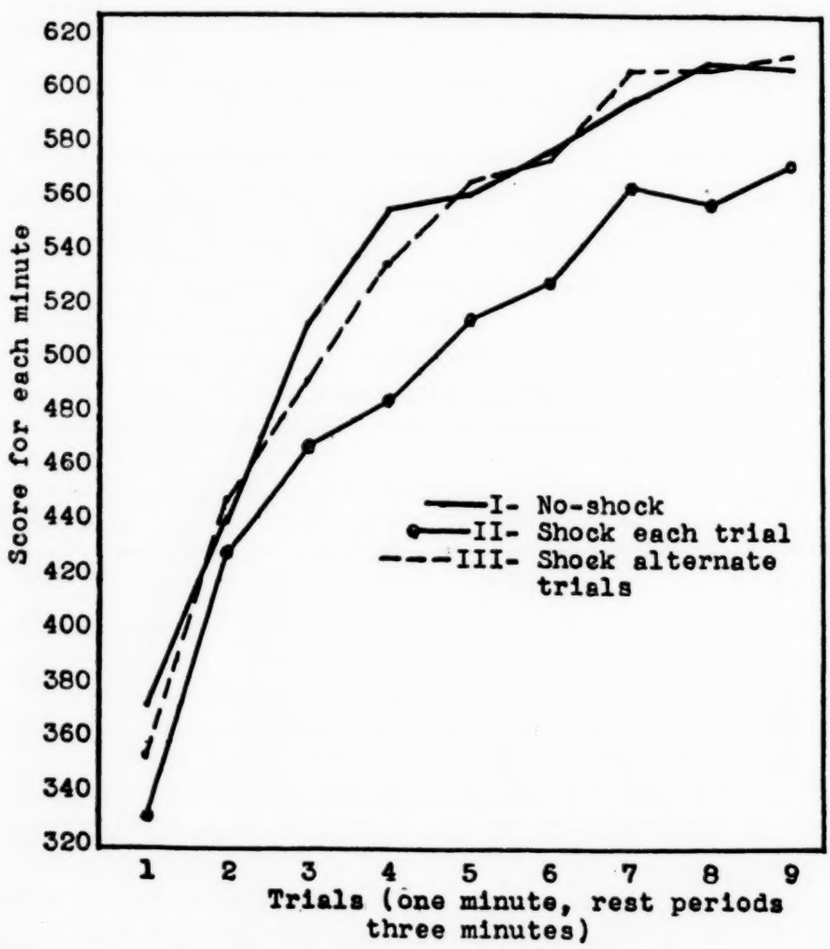
TABLE 1

Average Raw Scores

Trials	Situation I Control Group 17 Subjects	Situation II Shock Each Trial 11 Subjects	Situation III Shock Alternating Trials 27 Subjects
1	369	330	354
2	439	430	445
3	511	466	491
4	556	483	539
5	560	516	563
6	579	532	576
7	599	564	607
8	611	556	610
9	609	570	611
Total gain.....	242	240	257
Total percentage gain....	40	42	42
Ave. percent gain per trial	5	5.25	5.25

Each trial was one minute long with rest periods of three minutes. In Situation II each subject received a series of induction shocks during each trial whenever the stylus lost contact with the target. In Situation III each subject received shocks during trials 2, 4, 6 and 8 only. There is a slight difference between the total gain of the control group and those of the situations involving shock in favor of the groups receiving shocks. This difference is not significant and for practical considerations would be negligible.

Further analysis of Table 1 and Fig. 1 shows that the scores of the subjects who received electric shocks during each trial were consistently lower on all the trials than the scores of the other two groups. Because of the similarity in the total amount of gain for all three situations it would seem more reasonable to attribute the lower scores throughout



the learning curve in Situation II to the disrupting effects of the electric shock rather than to original difference in ability of the groups. We place this interpretation upon the obtained differences in the light of previous experimental findings to the effect that differences in original learning ability accompany differences in learning rate.

Table 2 gives the statistical comparison of the various conditions and experimental situations and reliability of the differences. The first comparison between the gains of the shock-trials and the non-shock trials for 27 subjects in

Situation III shows a mean difference of 13.5 in favor of the shock-trials; however, the critical ratio of 1.8 is hardly great enough to be of real significance. It is a difference, however, and the question arises whether this difference is due to a facilitative effect of the electric shock or to the position of the shock-trials in the series of trials for each subject. In view of the fact that the general learning curve for Situation II (shock each trial) was lower throughout than those for

TABLE 2

COMPARISONS OF EXPERIMENTAL GROUPS AND RELIABILITY OF DIFFERENCES

Number of Comparison	Experimental Conditions	No. of Trials	Mean	S.D. Dis.	Diff.	C.R.
One						
Situation III	Non-shock trials	108	26	44		
27 subjects	Shock trials	108	39.5	64	13.5	1.8
Two						
Situation I	Gain for trials 2, 4, 6, and 8	68	35	51		
17 subjects	Gain for trials 3, 5, 7 and 9	68	28	52	7.0	0.8
	12 subjects who feared shock					
Three	Shock-trials	48	37	47		
Situation III	15 subjects did not fear shock					
	Shock-trials	60	41	71	4	0.3
	12 subjects who feared shock					
Four	Non-shock trials	48	25	39		
Situation III	15 subjects did not fear shock					
	Non-shock trials	60	29.4	47	4.4	0.5
Five	4 subjects who feared shock					
Situation II	All trials	32	30.5	44		
Shock, all	7 subjects did not fear shock					
trials	All trials	56	28.5	60	2.0	0.2

the other situations would point to the interpretation of a deleterious effect of the electric shock. However, comparison No. 2 (Table 2) for the control group between the gains of trials number 2, 4, 6 and 8 and the gains of trials number 3, 5, 7 and 9 shows a mean difference of 7.0 and a critical ratio of less than one. This indicates that position in the series of trials as a factor in accounting for the gains made in the shock-trials for Situation III seems to play some part. Furthermore, on the basis of these data, electric shocks administered during alternating trials seemed to have a facilitative effect on learning.

In consideration of the problem whether electric shock really constitutes punishment we requested each subject to indicate after the experimental session whether the shocks were annoying or disrupting. On the basis of the answers to these questions we divided all the subjects who received shocks into two groups, namely, those who feared or were annoyed by shocks and those who were not afraid or were not annoyed by the shocks. Comparisons 3, 4, and 5 in Table 2 give the differences between these two groups for the two experimental situations in which electric shocks were administered. In comparisons 3 and 4 we found a small difference in favor of the subjects who did not fear the shocks, whereas in comparison 5 involving the experiment in which electric shocks were given during each trial there was a small difference in favor of the subjects who feared shocks. None of these differences, however, are statistically significant.

Summary

In summarizing these results on the effect of electric shock on learning in eye-hand coördination in the human subject our conclusions must be guarded because of the relative statistical insignificance of the differences between situations involving shocks and those in which shocks were not a factor. There was little or no difference in the total percentage gain or the average gain per trial between the control group and the two groups receiving shocks. The average scores for the group which received shocks during each trial were consistently lower in all nine trials than the control group or the group which received shocks during alternating trials. Conversely, the scores made in the shock-trials for the group which received shocks during alternating trials were higher than the scores in the non-shock trials. This and the former conclusion are contradictory, and presumably point to the hypothesis that the persistence of the electric shock is disrupting to learning whereas its occurrence during alternating trials is facilitative. The factor of the position of the shock-trials in the series of trials carried some weight in that the scores for these same trials for the

control group were slightly higher than those in the other trials. The differences between the subjects who were afraid or annoyed by the shocks and those who were not were too small to be of any real significance.

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